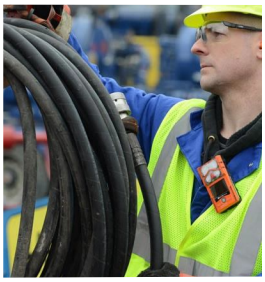
OTD

Operations
Technology
Development

RESEARCH PROJECT SUMMARIES 2021



Operations Technology Development, NFP

RESEARCH PROJECT SUMMARIES

2021

Legal Notice

This report was prepared by Operations Technology Development, NFP (OTD), as an account of the results of work sponsored by OTD. Neither OTD, the members of OTD, nor any person acting on behalf of any of them:

- Makes any warranty or representation, express or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately-owned rights. Inasmuch as many projects are experimental in nature, the technical information, results, or conclusions cannot be predicted. Conclusions and analysis of results by OTD represent OTD's opinion based on inferences from measurements and empirical relationships, which inferences and assumptions are not infallible, and with respect to which competent specialists may differ.

- Assumes any liability with respect to the use of, or for any and all damages resulting from the use of, any information, apparatus, method, or process disclosed in this report; any other use of, or reliance on, this report by any third party is at the third party's sole risk.

Chairman / President's Letter

The natural gas infrastructure provides the vital link in delivering energy to millions of homes, businesses, and industrial customers. Serving to maintain and improve the safety, efficiency, and reliability of this infrastructure is Operations Technology Development (OTD) – a not-for-profit collaborative organization representing 28 member companies who serve over 60 million customers in the U.S., Canada, and France.

OTD's work is becoming even more important as governments, utilities, and technology developers grapple with the dual imperative to reduce greenhouse gas emissions while keeping energy affordable and resilient. Our projects help enable the use of today's robust infrastructure to meet the industry's future energy goals. This ability relies heavily on the vision, guidance, and support provided by our members. We prioritize resources to focus on the most critical needs, addressing challenges that are more varied than ever.

This report provides summaries of more than 100 projects in the 2021 OTD program and includes an overview of some of OTD's most significant past achievements. This year, OTD is cofunding projects from DOT PHMSA, as well as DOE ARPA-E, which provide additional financial leverage and further demonstrates the importance and impact that OTD has for its stakeholders.

Example projects include: evaluating the impacts of hydrogen blending; technologies to prevent third-party damage; methodologies to understand and mitigate methane emissions; and technologies to understand and validate risks to pipeline integrity. All of these projects are core to the industry's success in delivering a safe, reliable, affordable, and environmentally conscious energy solution.

OTD has been making the industry smarter, safer, and more environmentally friendly by helping to enable renewable fuels, developing and adapting technologies for information management, risk management, system inspections, cybersecurity, material tracking, and other areas.

The key to OTD's success is the involvement and support of its members – gas operations experts and engineers from the industry's leading energy providers – who identify, select, fund, and oversee research efforts aimed at their specific customer needs.

We appreciate your interest in our project portfolio and we look forward to a future of even better things to come!

OTD Members

> Ameren Illinois
> APGA Research Foundation
> Atmos Energy Corporation
> Avista Utilities
> Consolidated Edison Co. of NY, Inc./ Orange & Rockland Utilities, Inc.
> Dominion Energy / Dominion Energy North Carolina
> Duke Energy Corporation / Piedmont Natural Gas Company, Inc.
> Enbridge Gas Distribution Inc.
> Exelon
> GDRF
> Intermountain Gas Company
> Liberty Utilities
> Louisiana RDC
  - Atmos Energy Corporation
  - CenterPoint Energy, Inc.
  - Entergy Corporation
> National Fuel Gas Distribution Corporation
> National Grid
> New York State Electric & Gas Corp. / Rochester Gas and Electric
> Nicor Gas
> NiSource Inc.
> NW Natural
> Oklahoma Natural Gas
> Pacific Gas and Electric Company
> Peoples Gas
> Southern California Gas Co., a Sempra Energy Utility
> Southwest Gas Corporation
> Spire (Alabama)
> TECO Peoples Gas
> Washington Gas

Ron Bridgewater
Chairman of the Board

Ronald Snedic
President

Results in Use

Since 2003, the OTD program has provided utilities, pipeline companies, service providers, and others in the natural-gas-delivery business with innovative tools, enhanced processes, and advanced equipment for improving gas system operations.

These products represent the results of OTD efforts to build a stronger industry infrastructure, enhance system integrity, and improve the efficiency of a wide range of operations activities.

Selected OTD-Developed Products in the Marketplace

Virtual Reality Training
Pixo VR

OTD partnered with PIXO VR to create a proof-of-concept Virtual Reality Training module designed to make emergency-response training more efficient and effective for a new generation of field technicians. The team created a new suite of highly relevant and fully immersive training simulations with valuable features such as interactive 3D environments for superior trainee immersion. This groundbreaking new training delivers more meaningful experiences, reinforcing critical, multi-step, inspection and safety protocols.

Contact: Sean Hurwitz
248-996-8298
sean.hurwitz@pixovr.com

UtilAlert Excavation Notification System
Hydromax USA

A GPS monitoring system for excavation equipment was developed to periodically transmit active excavation-equipment-location information to a portal. The system monitors the behavior of excavators and other equipment entering a utility right of way to characterize its behavior as safe or threatening. The proper alerts are generated to notify the excavator operator and the utility to take the necessary actions.

Contact: Andy Scott
281-684-7673
www.utilialert.com

.

Jameson Directional Entry Tool and Live Tracer
Jameson, a Spartaco Company

This directional tool enables vertical insertion of tracer rods and cameras into live gas mains, facililtating the difficult first bend of the entry. It operates on live mains with no blow by and is compatible with keyhole procedures (fits 24-inch minimum keyhole). The tool can be used on mains as small as two inches in diameter; rotates 360 to insert in either direction; and fits most camera heads.

Contact: Brad Kokoski
803-222-8454
www.jamesonllc.com

Large-Diameter, Medium-Pressure Inflatable Stoppers
Mainline Control Systems

The Kleiss MCS Flow Stopping System is used to stop the flow of gas in polyethylene, steel, cast-iron, and PVC pipes at diameters up to 18 inches and pressures up to 60 psig. The system, which is manufactured in Europe, was investigated through OTD to validate its operation and potential savings in the U.S. gas industry.

Contact: Wade Farr
812-459-3936 wfarr@mainlinecs.com
www.mailinecontrolsystems.com

Portable Methane Detector (PMD)
SENSIT Technologies

This handheld SENSIT® PM uses optical detection to provide sensitivity and cost advantages over conventional techniques employing flame ionization detectors. The PMD provides the efficiency of leak surveys, is less costly to maintain than other technologies, and can detect leaks from low ppm to 100% gas.

Contact: Scott Kleppe
219-465-2700
jScottK@gasleaksensors.com
info@gasleaksensors.com

IRED Infrared Portable Ethane Detector
SENSIT Technologies

This easy-to-use handheld detector was developed for use in the field to discriminate natural gas leaks from other sources of methane (e.g., swamp gas, landfill gas, and engine exhaust) and detect trace levels of ethane. The detection of ethane can be used as a fingerprint for natural gas in situations where the origin of a methane leak signal is questioned.

Contact: Scott Kleppe
219-465-2700
jScottK@gasleaksensors.com
info@gasleaksensors.com

Acoustic Pipe Locator (APL)
SENSIT Technologies

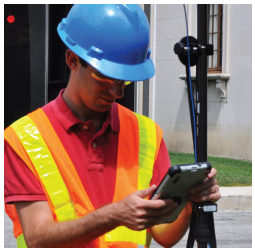
SENSIT's ULTRA-TRAC® APL acoustic-based pipe locator provides the ability to locate plastic pipes before excavations and construction. Now commercially available, in tests the system was shown to be capable of detecting multiple buried plastic pipes at depths up to five feet.

Contact: Scott Kleppe
219-465-2700
jScottK@gasleaksensors.com
info@gasleaksensors.com

LocusIQ for Intelligent Inspections
LocusView

A software platform developed through OTD is now part of the LocusView mobile product suite to allow users to collect new installation data directly within a GIS environment. Applications to integrate real-time, sub-foot accurate GPS and barcode scanning are included.

Contact: Alicia Farag
847-387-9412
alicia@locusview.com
www.locusview.com



LocusMap Mobile GIS Solution
LocusView

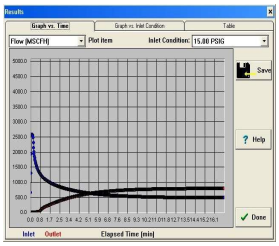
This system maps new installations with comprehensive tracking and traceability data, creating GIS features in a format that allows field-collected data to be directly integrated into the enterprise GIS. Barcode scanning and high-accuracy GPS automate the system and help create high-accuracy maps.

Contact: Alicia Farag
847-387-9412
alicia@locusview.com
www.locusview.com

LocusSurvey for Tracking Leak-Survey Routes
LocusView

LocusSurvey uses tablet computers and GPS to track leak-survey routes. The GPS breadcrumb trail is overlaid in a GIS to track pipe segments that are surveyed to provide real-time reporting and monitoring. LocusSurvey eliminates paper maps and records, automating the process of documenting surveys and leak locations.

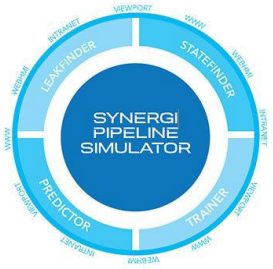
Contact: Alicia Farag
847-387-9412
alicia@locusview.com
www.locusview.com



Pipeline Purging Program Update
Bradley Bean

The Pipeline Purging Program calculates the purge time, purge pressure, gas flow rate, and the required inert gas volume for the user's specific pipe geometry. The updated program uses a modern web-based platform will allow utilities to utilize the program for planning pipeline purging operations.

Contact: Bradley Bean
719-578-9391
sales@b3pe.com



Synergi Pipeline Simulator
DNV GL

DNV GL's pipeline integrity software, Synergi Pipeline, is a scalable company-wide risk- and integrity-management system. It enables safe and efficient pipeline operations, documents risk, and provides users, including upper management, with a clear overview of the integrity of distribution networks and offshore and onshore pipelines.

Contact: Michael Moore
717-724-1900
michael.moore@gl-group.com
www.dnvgl.com

Lift Assists for Pavement Breakers and Rock Drills
Integrated Tool Solutions, LLC

These devices assist workers in lifting pavement breaker and rock drills after the bits break through surface pavements and rocks and need to be repositioned for the next penetration. By eliminating the need to manually lift and re-position the heavy tools, the lift assists make breaking easier and less physically demanding.

Contact: Ryan Purczynski
951-929-4808
rpurczynski@integratedtoolsolutions.com
www.integratedtoolsolutions.com

Keyhole Pipeline Inspection Camera System
ULC Robotics

The PRX250K keyhole camera is an internal inspection system designed for visual assessment of live mains through conventional pits or small keyholes. The system is easily maneuverable through tight bends, allowing utilities to examine pipe segments without the need to drill additional access holes.

Contact: Greg Penza
631-667-9200
gpenza@ulcrobotics.com
www.ulcrobotics.com

Metallic Joint Locator (MJL)
SENSIT Technologies

The SENSIT Ultra-Trac® MJL accurately locates bell joints, repair clamps, and service connections on metallic piping systems, significantly reducing excavation areas and pavement restoration costs. In field tests, the MJL was also able to detect bell and spigot joints for an eight-inch-diameter water main buried at a depth of six feet.

Contact: Scott Kleppe
219-465-2700
jScottK@gasleaksensors.com
info@gasleaksensors.com

Information on additional available products can be found at the OTD website: **www.otd-co.org**

Informational Products

Selected OTD-Developed Technical Reports

In addition to the development of new tools, processes, and products, OTD supports research that results in useful information on various aspects related to gas delivery and operations. Listed here are some of the key reports developed under OTD sponsorship.

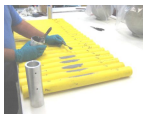
PIPE & LEAK LOCATION

RFID Marker Technology Implementation Guidelines
A set of guidelines was developed for the implementation and application of integrated Global Positioning Systems (GPS), Geographic Information Systems (GIS), and "Smart Tag" technologies to streamline public-improvement project planning and prevent damage caused by excavations.

Cross Bores Best Practices Guide & Video
Significant research was conducted to investigate gas line/sewer line cross bores. The Guide and "how-to" videos (available through the OTD website) provide recommendations and procedures for preventing and detecting cross bores. (OTD-12/0003)

Residential Methane Gas Detector Program
This report provides results of a project initiated to determine whether commercially available combustible gas detectors are susceptible to giving false positive responses to an assortment of typical household chemicals, including ammonia, ethanol, acetone, toluene, isobutane, ethyl acetate, isopropanol, heptane, and hydrogen. (OTD-13/0003)

PIPE MATERIALS, REPAIR & REHABILITATION



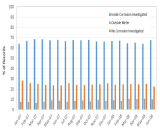
Repair Wrap for Polyethylene (PE) Systems
Researchers evaluated a new composite pipe wrap system for the repair of mechanically damaged polyethylene gas pipe. The repair system has the potential to lower repair costs, reduce repair times, and minimize disruptions. (OTD-17/0001)

Liners/Composites for the Rehabilitation of Distribution and Transmission Lines
A report titled *Transmission Infrastructure Roadmap* was prepared to address the implementation of composite piping materials in the rehabilitation of gas transmission systems. This report includes information on composite pipes, trenchless repairs, and cured-in-place structural liners.

Evaluation of Structural Liners for the Rehabilitation of Liquid and Natural Gas Piping Systems
This report details the results of testing conducted to evaluate the long-term performance of liners and composites used in trenchless operations for the rehabilitation of aging gas distribution and transmission lines.

Polyurea Coating Testing and Assessment for Gas-Industry Use
A Final Report is available on research into field-applied polyurea coatings for gas industry use. Through a new initiative, long-term field trials will be conducted to evaluate these additional coatings and determine a cost-effective coating-application method and process. *(Project Summary, p. 15)*

Electrofusion Coupling Evaluation and Best Practices
Researchers investigated techniques used to perform electrofusion joining of plastic gas pipe in an effort to develop guidelines for the use and operation of electrofusion coupling. With a detailed set of guidelines, the gas industry can enhance the performance and safety of its plastic piping systems.



Risk-Based Atmospheric Corrosion / Leak Survey Considerations

To address new regulations, researchers reviewed historical and current data on indoor gas service piping. In addition, thousands of recent inspections on outdoor and indoor services were collected and statistically analyzed to determine the trends and drivers behind corrosion rates. A White Paper is available (OTD-15/0004).

EXCAVATION & SITE RESTORATION

Evaluation of Lightweight Jackhammers

A research team evaluated the performance of currently available lightweight pneumatic and hydraulic jackhammers with respect to their effectiveness in breaking asphalt and concrete pavement, while considering other operational factors such as noise, vibrations, operator impact, and performance.

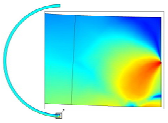
Cold-Patch Products Performance Results

This report provides the results of a testing program that evaluated nine commercially available cold-patch products, including two products introduced in the market as “green” patches. Cold- and warm-weather tests were performed and repeated moving loads were applied with a wheel-loading machine that conducted 50,000 wheel passes.

Evaluation of Flowable Fill Around Buried Pipes

Flowable fill is required by some agencies for use as backfill material for pipe repairs, rehabilitations, and other operations. Presented in this report are the results of performance tests of flowable fill, including the effects of flowable fill on pipeline corrosion and on the detection of gas flow and leaks through the backfill. (OTD-07/0004)

PIPELINE INTEGRITY MANAGEMENT & AUTOMATION

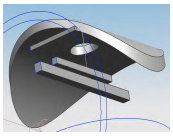


Correlating Pipeline Operations to Potential Crack Initiation, Growth, and Arrest

To help to reduce risks associated with vintage transmission pipeline materials, researchers developed and validated a model for pipeline operations that correlates pressurization to pipe crack-growth rates, crack initiation, and crack arrest. A Final Report was issued in 2016 that includes a training manual on the use of a Critical Crack Propagation Pressure Calculator that provides a convenient and simple way to calculate the critical pressure at which an axial crack will propagate.

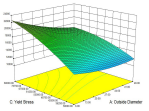
Hydro-Testing Alternative Program

Researchers developed and deployed a Critical Flaw and Critical Wall Loss Calculator that allows pipeline operators to determine if an inspection technology could detect a crack-like flaw and/or wall loss that would fail a pressure/hydro-test at a particular pressure. A Phase 3 Final Report was issued in 2016.



Establishment of Yield Strength Using Sub-Size Samples Without Gas-Line Shutdown

This report presents the results of a multi-phase project is to develop, validate, and obtain regulatory acceptance for a method to establish pipeline yield strength that allows for a less expensive sampling procedure that does not require the line to be taken out of service. (OTD-13/0005).

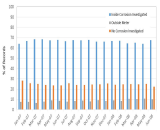


Leak-Rupture Boundary Report and Calculator

This report and associated software allows operators to determine the leak-rupture boundary for a pipe segment based on properties such as the diameter, toughness, and yield strength. Operators can use the calculator for risk modeling and consequence analysis. (OTD-13/0002 and OTD 13/0004)

Field-Applied Pipeline Coatings: Short- and Long-Term Performance

This report presents the culmination of a 10-year research program to assess more than 80 different commercially available field-applied pipeline-coating products. The goal was to establish an unbiased, third-party basis for operators to select the most appropriate coating system for particular applications.



Risk-Based Atmospheric Corrosion / Leak Survey Considerations

To address new regulations, researchers reviewed historical and current data on indoor gas service piping. In addition, thousands of recent inspections on outdoor and indoor services were collected and statistically analyzed to determine the trends and drivers behind corrosion rates. A White Paper is available (OTD-15/0004).

EXCAVATION & SITE RESTORATION

Evaluation of Lightweight Jackhammers

A research team evaluated the performance of currently available lightweight pneumatic and hydraulic jackhammers with respect to their effectiveness in breaking asphalt and concrete pavement, while considering other operational factors such as noise, vibrations, operator impact, and performance.

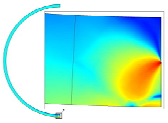
Cold-Patch Products Performance Results

This report provides the results of a testing program that evaluated nine commercially available cold-patch products, including two products introduced in the market as “green” patches. Cold- and warm-weather tests were performed and repeated moving loads were applied with a wheel-loading machine that conducted 50,000 wheel passes.

Evaluation of Flowable Fill Around Buried Pipes

Flowable fill is required by some agencies for use as backfill material for pipe repairs, rehabilitations, and other operations. Presented in this report are the results of performance tests of flowable fill, including the effects of flowable fill on pipeline corrosion and on the detection of gas flow and leaks through the backfill. (OTD-07/0004)

PIPELINE INTEGRITY MANAGEMENT & AUTOMATION

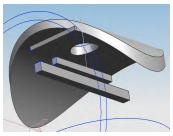


Correlating Pipeline Operations to Potential Crack Initiation, Growth, and Arrest

To help to reduce risks associated with vintage transmission pipeline materials, researchers developed and validated a model for pipeline operations that correlates pressurization to pipe crack-growth rates, crack initiation, and crack arrest. A Final Report was issued in 2016 that includes a training manual on the use of a Critical Crack Propagation Pressure Calculator that provides a convenient and simple way to calculate the critical pressure at which an axial crack will propagate.

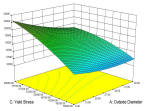
Hydro-Testing Alternative Program

Researchers developed and deployed a Critical Flaw and Critical Wall Loss Calculator that allows pipeline operators to determine if an inspection technology could detect a crack-like flaw and/or wall loss that would fail a pressure/hydro-test at a particular pressure. A Phase 3 Final Report was issued in 2016.



Establishment of Yield Strength Using Sub-Size Samples Without Gas-Line Shutdown

This report presents the results of a multi-phase project is to develop, validate, and obtain regulatory acceptance for a method to establish pipeline yield strength that allows for a less expensive sampling procedure that does not require the line to be taken out of service. (OTD-13/0005).

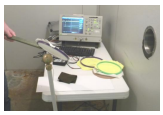


Leak-Rupture Boundary Report and Calculator

This report and associated software allows operators to determine the leak-rupture boundary for a pipe segment based on properties such as the diameter, toughness, and yield strength. Operators can use the calculator for risk modeling and consequence analysis. (OTD-13/0002 and OTD 13/0004)

Field-Applied Pipeline Coatings: Short- and Long-Term Performance

This report presents the culmination of a 10-year research program to assess more than 80 different commercially available field-applied pipeline-coating products. The goal was to establish an unbiased, third-party basis for operators to select the most appropriate coating system for particular applications.



UV Degradation and Static Buildup Testing of Personal Protection Equipment Fabrics

Researchers tested various utility-vest materials to determine if degradation is caused by ultraviolet light and to evaluate the potential for static buildup to become hazardous. The results of safety vest testing are available in technical reports.

Ignition Testing of Electronic Devices

In this project, handheld electronic devices were tested to determine if ignition occurs in the presence of a flammable methane/ air mixture. Laboratory tests demonstrated a large margin of safety under the scenarios investigated. (OTD-12/0001)

Intelligent Utility Installation Process

This report provides a methodology, field process, and a data model for capturing data during new utility installations. The process is used to capture information regarding the location, materials, installation process, environmental considerations, and other factors. (OTD-12/0002)

Tracer Wire for HDD Applications

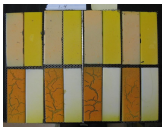
Extensive research and testing culminated in the release of a report that provides valuable information on the properties and performance of various tracer-wire products for use in horizontal directional drilling (HDD) operations. (OTD-13/0001)

Enterprise Decision Support System

This report presents the results of efforts to create a technology roadmap for the development of an Enterprise Decision Support System to integrate gas-system data and knowledge from various sources into a single information source to support decision making.

Assessment of Vehicle-Barrier Design for Aboveground Facility Protection

Investigators compiled the latest information on the design, regulations, and installation practices of structural vehicle barriers used to protect aboveground utility facilities from vehicular damages. The Final Report also includes a review of various state and federal safety guidelines.



Study of Low-Impact Markings

A variety of paints, materials, and techniques were tested and characterized in an effort to identify products and methods that can be used for temporary utility marking. Information developed in this study allows users to identify the most appropriate marker type for a given environment to achieve the desired marking duration. (OTD-11/0002)

Solar-Powered Remote Monitoring

In this study, solar-powered devices were investigated as power sources for the remote monitoring of various gas utility facilities to more cost-effectively obtain rectifier data, pipe-to-soil measurement, pipe-to-casing readings, and other information.

Integrating GPS into Routine Operations

This report provides a set of recommendations and GPS implementation strategies developed through pilot programs, literature searches, and reviews of existing applications. Operations that were considered included meter reading, leak surveying, new installations, corrosion monitoring, and valve inspections.

DVDs for Training First Responders

DVD training products help gas companies better educate first-responding personnel about natural gas emergencies. Learning modules with realistic scenarios cover a variety of issues to enhance public and worker safety. The product also serves to improve emergency-response effectiveness and coordination.

METHANE EMISSIONS/DETECTION & GAS QUALITY

Siloxane Concentrations in Biomethane

Biomethane from various waste products could provide consumers with a significant source of "green" renewable energy. In efforts to help develop this green resource, a study was conducted into siloxane – one of the potential constituents in biomethane – to assess its influence on health, the environment, and gas-fired appliances.

Field Measurement Program to Improve Uncertainties for Key Greenhouse Gas Emission Factors for Distribution Sources

This report summarizes the results of field surveys conducted at six natural gas utilities. With the support of the American Gas Association, research updated emissions factors for metering stations, regulating stations, and customer meters. (OTD-10/0002)

Improving Methane Emission Estimates for Natural Gas Distribution Companies

This report details Phase 2 of a four-phase field-testing program to evaluate gas leak rates from belowground pipelines, provide a simplified procedure that can be used to monitor pipeline leaks from surface measurements, and update the methane emission estimates for the main lines in a distribution system.

Pipeline-Quality Methane: North American Guidance Document for Introduction of Dairy-Waste-Derived Biomethane into Existing Natural Gas Networks

The guidance document provides reference and recommendations for the consideration of biomethane from dairy-waste digestion for introduction into gas pipeline networks. The report details results of a biogas/biomethane Gas Technology Institute research program.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

OTD RESEARCH PROJECT SUMMARIES 2021

Table of Contents

Project **Page**

CONSTRUCTION/INFRASTRUCTURE TECHNIQUES *(cont.)*

Project **Page**

METHANE EMISSIONS/DETECTION & GAS QUALITY

Project **Page**

INTELLIGENT UTILITIES

RISK & DECISION ANALYSIS/MODELS

PIPE MATERIALS, REPAIR & REHABILITATION

In this area, researchers focus on various aspects related to the evaluation and development of materials and processes used to maintain, repair, and rehabilitate gas piping systems.

Current efforts include projects to evaluate pipe coatings and composite repair wrap.

R&D results from this area – developed in state-of-the-art testing facilities and demonstrated in the field – contribute to improvements in system safety, deliverability, and integrity.

.

In-Service Field Evaluation of Polyurea Coating Systems

Research into field-applied polyurea coatings for gas industry use is being conducted through long-term field trials designed to evaluate coatings and determine a cost-effective coating-application method and process.

Project Description

In recent years, gas utilities have expressed increased interest in using plural-component "polyurea" coatings for service applications such as vaults, pipe on bridge crossings, pipe for horizontal drilling applications, above-ground meter sets and distribution equipment, and vehicle truck beds/underbodies.

In general, polyurea coatings have exceptional high elongation and toughness. Polyureas also offer rapid application rates, fast curing (< 1 minute), and a quick return of components to service. In addition, they can have strong abrasion resistance and excellent encapsulation characteristics. Some systems are available in high-pigment UV-inhibited formulations, making above-ground applications acceptable.

The most problematic application of polyurea coatings is related to potential coating damage from cathodically protecting the pipe. Polyureas are generally known to perform relatively poorly compared to fusion-bonded epoxies (FBE) in ASTM cathodic-disbondment (CD) testing. However, due to their exceptional impact resistance, many fewer holidays should be expected to form.

In Phase 1 of this project, a comprehensive evaluation of polyurea pipe coatings was conducted.

Tests were conducted to determine: cathodic disbondment, impact resistance, abrasion resistance, UV resistance, and corrosion resistance.

Two types of polyurea coatings from performed well in laboratory testing and appeared promising for use in the natural gas industry. Their impact and corrosion resistance out-performed the benchmark liquid epoxy coating.

In the current Phase 2 initiative, coatings are being further tested through long-term field trials in several applications.

Deliverables

Deliverables will include a report on the application of the coatings at various field sites. The report will also provide guidance for the polyurea applications method and process.

Regulator bolt rust in November 2015 (left) and in April 2017 (right).

Benefits

This research will provide utilities with the comparative, sound engineering data necessary to make decisions regarding the use of polyurea coatings.

Technical Concept & Approach

- Identification of Field Test Sites and Coating Applicators
- Establishment of a Field Testing Matrix
- Evaluation of Field-Coating Applications
- Coating Evaluation, and
- Guidance for Polyurea Applications.

Results

The overall performance of polyurea coating was evaluated and compared with a benchmark liquid epoxy coating.

An installation was made in New York state. The research team documented the conditions of the pipe before, during, and after the installation. Surface profile measurements were taken after pipe blasting and before the coating was applied three times and in five different locations in order to obtain a representative sample size of measurements. Once the pipes were sandblasted, the surface was coated with a polyurea sprayed onto the pipe and allowed to cure. Thickness measurements were taken at different locations along each of the pipes. After the minimum target coating thickness had been achieved, the pipes were spray coated with a 3-4 mil topcoat of yellow paint for visibility and safety.

In 2017, the coated pipe segment in New York was inspected (about 18 months after its initial coating of polyurea). Researchers reported that the coating appears to be holding up well.

At the site, coating-thickness measurements were taken at 12 locations along pipe sections in sets of four places around the diameter of the pipe at each location, for a total of 48 measurements.

A component of the inspection focused on rust formation. At first glance, very small pinpoint-style rusting seems to have formed in areas along the pipe. A possible explanation for this formation is overspray, which is a common issue with the application of polyureas due to its fast curing time. If it is only deposited on top of the coating, overspray should not be detrimental. If overspray occurs on the pipe surface prior to the application of the coating, however, delamination could result. The pattern will not be classified as rust at this time, but dark, dotted areas will be monitored and their growth patterns will be noted.

Very small paint blistering was observed in a few locations along the length of the aboveground pipe. These blisters are very small and few in concentration. The blisters are most likely osmotic blistering due to temperature variations of the effluent and ambient temperatures. They are hard, firm blisters and if they are cut open, we can assume that one will find moisture but no corrosion below. The liner keeps the moisture from contacting the pipe surface and since no oxygen is present, there is no corrosion.

No activities were conducted since the fourth quarter of 2018, when researchers travelled to a site to inspect the polyurea coating. The coating was installed three years prior to the time of inspection. No major signs of corrosion were found during the inspection and the coating thickness, surface salt concentration, rust pattern development, and paint blistering was measured at multiple locations on the pipe surface.

The most noticeable difference observed occurred in the coatings color. The coating is a slightly paler yellow than it had been at the one-year inspection. Some spots of rust are also visible at the flange locations on the valves.

Status

A Final Report is being prepared.

The final inspection of the coated pipe was conducted in May 2021.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Composite Repair Wrap for Polyethylene Systems

Researchers are evaluating a composite pipe wrap system for the repair of mechanically damaged polyethylene gas pipe. The repair system has the potential to lower repair costs, reduce repair times, and minimize service disruptions.

Project Description

With existing polyethylene (PE) pipe repair methods, typically a short section of the distribution system is shut down and bypassed while the damaged pipe section is cut out and replaced. This approach is time consuming, expensive, and requires multiple excavations and complicated procedures.

In this project, researchers are investigating a pipe wrap system for the repair of PE pipe components that shows promise of being a fast, easy-to-use, durable, and cost-effective method for PE pipe repair. This method provides direct bonding of composite materials to the PE pipe surface with minimal surface preparation. The composite material may be either resin pre-impregnated fiberglass cloth or field-impregnated fiberglass that adheres to PVC, fiberglass, concrete, and all metal pipes. According to the manufacturer, the PE pipe repair method and materials will also provide abrasion and impact resistance to the PE pipe. A single system can be used to repair pipes and/or fittings of various diameters, sizes, and shapes.

Although composites have been used for more than 20 years to remediate steel piping, the ability to repair PE pipe was limited due to the inability of composites to bond to the PE material. The patent-pending pipe wrap technology overcomes this limitation.

A research team is conducting a thorough evaluation of the pipe-wrap system to develop information on the permanency and life expectancy of the repairs.

Deliverables

The deliverables for this project include testing reports detailing the performance of repairs made with the pipe-wrap system.

Benefits

PE pipe systems experience two common types of damages. The first type is third-party mechanical damage that results in pipe wall loss that requires immediate remediation where the only available option is to remove and replace the damaged section. The second type is longer-term damage which manifests from either crimp-type fittings or the crimping operation required to conduct a cut-and-replace operation, which introduces micro-cracks into the pipe wall. These micro-cracks can become problematic and can be considered as deferred remediation projects. Both types of damage, if left in their natural state, will result in leaks and/or other hazards. A practical PE permanent repair system will save time and money while minimizing service disruptions.

Technical Concept & Approach

The investigation of the pipe-wrap PE pipe-repair system focuses on applying the repair technique to different gas system components to evaluate effectiveness. Simulated defects are machined in each pipe specimen.

Pipe samples squeezed-off under pressure.

Most prepared samples undergo the following:

- Short-term hydrostatic burst testing
- Rate Process Method (RPM) analysis by performing long-term hydrostatic pressure testing at elevated temperatures, and
- Impact testing in general accordance with ASTM D2444 *Standard Test Method for Determination of the Impact Resistance of Thermoplastic Pipe and Fittings by Means of a Tup* (falling weight).

Results

In this project, various pipe specimens were prepared with simulated defects and subjected to testing. Based on specimens subjected to hydrostatic burst testing, it appears that the repaired two-inch-diameter pipe samples, irrespective of the pipe sample being heated or not during the repair process, are performing well.

Notched (gouged) pipe specimens were sent to the manufacturer, who designed and built a prototype heat-gun field tool used to apply the repair technology. This device is designed to clamp onto a pipe at either end of the repair area. The device has a variable temperature heating device and a custom-built nozzle that applies a constant temperature heat circumferentially around the pipe.

Dynamic thermo-mechanical analysis and squeeze-off evaluations were conducted. Pipe specimens were squeezed-off in accordance with ASTM F1041 and D2513 under 60 psig internal pressure at room temperature. Technicians prepared and wrapped two-inch-diameter medium-density PE pipe samples for burst and long-term hydrostatic strength testing at various temperatures. Dynamic mechanical thermal analysis of the wrap material was also completed.

In 2019, burst testing was completed on wrapped samples at 140°F, 176°F, and 194°F.

In 2020, the project team experienced significant downtime with its test rig. In light of persistent issues, the scope of work was modified. Instead of testing the samples via cyclic pressure loading, it was recommended to test the samples hydrostatically where they will be tested in a water bath and a suitable hoop-stress level (constant pressure) to generate failures in around 2,000 hours of test time.

Three sets of six samples (18) were tested. Researchers observed ductile failures at the squeeze ears on the "non-repaired" and ductile failures at the non-reinforced pipe on the "repaired" pipes. Visual inspection of the internal diameters of the specimens did not find any indication of SCG slits under the reinforcements, whereas there were a number of SCG slits under the non-reinforced pipe.

PE pipe repair machine heating tool assembly.

The project team did not observe any failures or onset of failures at the edges of the repairs. These test results indicate that the repairs are working as intended, that is, the repair patch is suppressing creep at the squeeze location.

Status

This project was completed and a Final Report is available.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

INSPECTION & VERIFICATION

Projects in this area focus on the development of tools and techniques to assist companies in enhancing safety and meeting integrity requirements in a cost-effective manner.

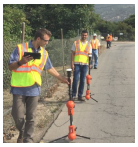
To meet the challenges of pipeline integrity management, researchers are developing pipe-inspection systems and other technologies for gas delivery systems.

Through R&D in this area, pipeline and distribution system integrity can be maintained and improved based on sound, scientific developments related to inspection, testing, and other activities.

Initiatives include efforts to develop self-healing coatings and a tool to detect coating disbondment and metal loss.

.

Tool for Detection of Cathodic Disbondment and Metal Loss



This project is focused on the development of a practical tool for detecting cathodic disbondment and metal loss. The technology would enhance the safety of steel gas piping systems by providing the ability to locate potential pipe-corrosion sites before leaks or serious metal loss occurs.

Project Description

A significant amount of the steel pipe used in gas distribution systems is more than 50 years old. To ensure system safety, these older pipes are regularly assessed for corrosion, which generally requires exposing the pipe for inspection and often requires the removal of a coating. Of specific concern is that corrosion can be severe under a coating disbondment when the fusion-bonded epoxy, coal-tar enamel, or field-applied tapes separate from the steel. Since exposing the entire pipe is prohibitively expensive, inspections are conducted that assume that a statistical sampling of an area is representative of the pipe condition.

The objective of this project is to develop, test, and demonstrate a platform for detecting coating disbondment and external corrosion by measuring magnetic fields from above ground. The technology incorporates sensors to detect magnetic fields, determine pipe orientation, plus computational means to extract coating disbondment and corrosion locations from this data.

In Phase 1 of this project, limited field testing found that the tool has strong potential for locating breaks in coatings and attached appurtenances from above ground. The objective of Phase 2 is to execute additional field tests to build a robust sample size from which to evaluate the tool's effectiveness.

Deliverables

Deliverables include a field-tested beta prototype, results of field tests, and reports summarizing the findings of field tests and outlining commercialization steps recommendations.

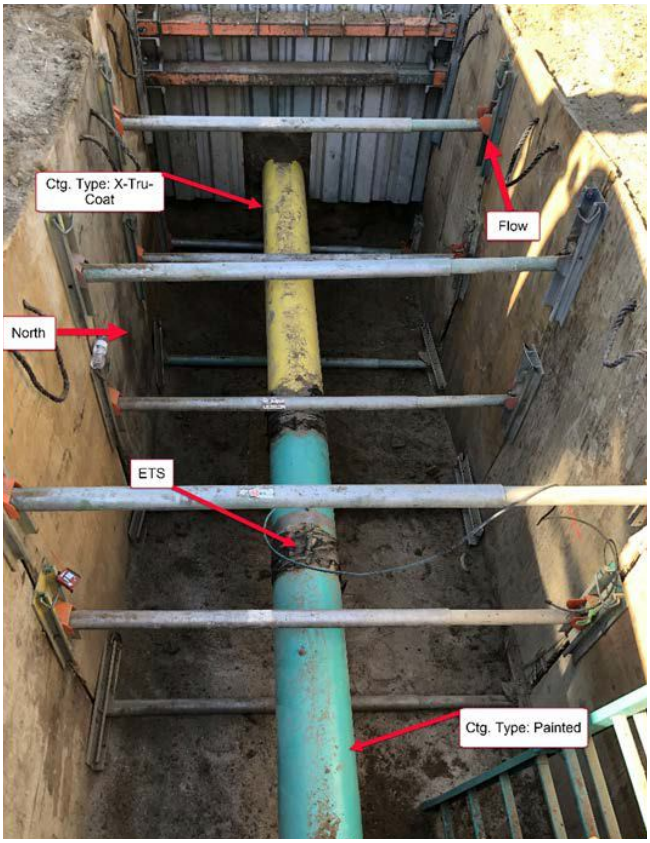
Benefits

The ability to locate potential coating disbondment and corrosion sites before serious metal loss or leaks occur will improve public safety. This technology can increase system knowledge of coated steel pipe without the need for excavation. In addition to providing assessment data, the method also generates Global Navigation Satellite System referenced maps of the facility surveyed. The ability to capture both by executing a single procedure would streamline the capture of integrity management data.

Technical Concept & Approach

The operating principle for the technology studied is to inject or induce a current on the pipe being surveyed that, in turn, generates an exterior electromagnetic (EM) field around the pipe. The next step is to carefully map the EM field around the pipe in three dimensions.

The properties and curvature of the exterior field will be influenced by the path of signal current through the pipe metal, coating, and surrounding soil. Unlike standard pipe locators that infer the pipe location from the field magnitude only, the system being developed also captures the phase angle of the signal.



Excavation site.

Creek crossing.

In order to accomplish the detection of flaws, a suite of sensors is moved along the pipeline route with stops at specific intervals to take readings. A pre-defined current excitation signal is placed on the metallic pipe in order to generate an external EM field that some of the sensors are tailored to receive. Measurements of this field allow the inference of the pipe location and orientation relative to the sensors. Data is automatically captured, then stored for post-processing to locate pipe and coating features. An end goal is for visualizations of the data to be available in the field.

In addition to multiple magnetometers to locate the pipe, the system integrates GPS location and timekeeping. Multiple systems can be linked wirelessly when longer baselines are needed to triangulate deeper pipes.

Results

Phase 2 of this project had the objectives of advancing understanding of results from earlier surveys as well as to build a more robust library of surveyed features for which the system is capable of detecting anomalies.

The first Phase 2 survey was conducted in 2017. There were three distinct sites identified in the operator's territory. The specific sites were chosen based on in-line inspection (ILI) data that had been previously collected. The three sites were all on a single pipeline in a largely agricultural area that included navigating a creek crossing, electric fence-enclosed pastures, and areas of dense

Closeup of external coating damage.

undergrowth vegetation. In multiple instances, the survey data was found to be in good agreement with the utility-provided ILI data.

The second Phase 2 survey was executed in 2018. Analysis of the mapping and current reading plots identified potential anomalies in some instances and nothing of note or required follow-up in others.

In July 2021, the third Phase 2 field site was surveyed. A close interval survey of cathodic protection on- and off-potentials had been conducted by the operator prior to the survey.

The equipment in hand is becoming unreliable, and no repair parts are available. The manufacturer released a system successor that is currently used for locating submerged pipes and cables. The company has not yet released a version for terrestrial applications.

Status

A Phase 2 Final Report was issued in December 2021.

Next steps involve defining the demand more clearly for technology to remotely assess the condition of buried pipes and coatings from above ground. The number of survey sites offered during the project was lower than anticipated. While several actionable anomalies were found during the surveys, not all were excavated. No false positives were found; the survey agreed with other techniques and excavations in the cases where no anomalies were anticipated.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Correlation of Surface to Through-Wall Properties of Pipe

In this project, researchers developed a technique that allows pipeline operators to determine the material properties of in-service pipe with minimal disruption to system operations. Specific activities focused on the developing relationships to equate surface properties to bulk material properties to allow nondestructive techniques to be used for material characterization when appropriate.

Project Description

Past research proved the ability of surface-indentation techniques (e.g., stress-strain microprobes and hardness testing) to accurately determine material properties of pipes within a localized area; however, variations in material properties through the wall are problematic for local interrogation techniques. This project focused on the development of relationships and modeling to relate surface-obtained, nondestructive properties to through-wall material properties to allow surface techniques to be used to support material property characterization of pipelines without complete records.

The project methods and models will advance the use of micro-indentation, micro-machining, in situ chemistry, and replicate microscopy analysis as accurate, efficient, and cost-effective tools for material property confirmation. They also will support future development of nondestructive techniques through the well-documented property variations across a representative sample set of pipelines typical in the industry.

This project was conducted with funding from the U.S. Department of Transportation's Pipeline and Hazardous Materials Safety Administration and OTD, with further in-kind funding from Arizona State University.

Deliverables

Deliverables include a database of through-wall properties by vintage for typical pipelines in service in the natural gas industry and comparison of nondestructive evaluation (NDE) surface-based testing techniques to

Several testing methods were used.

evaluation (NDE) surface-based testing techniques to full-wall destructive laboratory testing. The correlation between the NDE and laboratory tests was fully developed and advanced statistical and causal models were used to combine and enhance surface-based testing predictions of bulk properties.

Benefits

This project benefits pipeline safety, energy continuity, and integrity assessment programs since the developed techniques and models and validated testing technology will not require a line to be taken out of service or destructively cut out samples from the in-service pipeline.

The ability to characterize material properties – particularly yield strength – of in-service pipelines without taking the line out of service or removing samples will significantly reduce the cost of complying with existing and pending federal regulations.

Technical Concept & Approach

The approach taken to validate the surface-interrogation methods was to assemble a comprehensive database of material properties of pipeline steels, including surface and bulk chemistry; surface and bulk mechanical properties; and surface and bulk metallurgical grain size.

The project team:

- Analyzed the variance of the difference between surface and bulk measurements
- Developed a simple in-field procedure to remove a minimal outer layer from the pipe surface to reduce the variance between surface and bulk properties to an acceptable level
- Determined the robustness of recognized historic models for predicting the mechanical properties of the steels from other variables
- Developed casual models and advanced statistical and probabilistic models to account for differences between the surface and bulk properties
- Selected the most appropriate models, and
- Adjusted and validated the model.

Results

The correlations developed in this project allow surface-obtainable information from indentation and other surface testing techniques, surface chemistry analysis, and surface optical microscopy to be used for material property validation for pipelines. The project successfully measured and categorized the mechanical, chemical, and physical differences across a broad range of pipe sample walls through methodical full-wall and bulk testing as compared to surface-collected physical, mechanical, and chemical non-destructive evaluation testing.

Differences in yield strength between the surface derived values and bulk, full-wall were analyzed via a sensitivity study and explained through the changes in surface yield strength due to primary steel production processes, seam type, the pipe-forming process, and steel chemistry. All these factors/variables can be determined from surface testing.

Based on the extensive testing and analysis, an ambitious set of modeling tasks were completed. Successful models for yield strength and ultimate tensile strength were developed to predict bulk properties from purely surface-obtained information for yield strength and tensile strength.

The optimum causal models achieved a 95% confidence in yield strength predictions by overlapping the full-wall yield strength from laboratory tests.

Chemistry values were correlated successfully for 15 key elements, and the only significant variation of chemical properties across the pipe wall was noted from surface-to-bulk values for carbon and sulfur.

In 2020, testing of all 70 pipe samples was completed.

Status

This project is complete. A Phase 2 Final Report was issued in October 2021.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Development of a Long-Term Enhancement of Direct Assessment

The objective of this project is to provide a technically justifiable, augmented method to retain direct assessment as an acceptable integrity-assessment process for pipeline segments.

Project Description

The use of direct assessment (DA) for determining pipeline conditions is expected to be restricted from use as the *sole* inspection method if any one of five other inspection methods are "capable" of being used, namely: in-line inspection (ILI), pressure testing, hydrostatic spike testing, excavation and direct examination, and guided-wave testing. However, pipeline operators have a significant number of covered transmission assets that are not conducive to ILI and/or pressure or spike testing. Full pipe excavation and direct examination is often not possible or practical, and guided-wave inspection has limited range and restrictions on use.

The gas industry has expressed interest in a process improvement or enhancement to the current practice that would allow DA's continued, justified use for specific categories of transmission lines. This enhancement might include supplementation with other data or inspection technologies and increased preventative and mitigative (P&M) measures and surveys, but not require the same operational actions of ILI or pressure/spike testing.

This project builds upon three previous projects:

1. A hands-on, demonstration, testing, and analysis project titled *Demonstration of ECDA Applicability and Reliability for Demanding Situations*, and
2. A study titled *Improving the Performance of the External Corrosion Direct Assessment (ECDA) Methodology*, and
3. OTD project 4.20.a *(Safety Impact of Hoop Stress and Percentage of Specific Minimum Yield Stress Boundaries).*

The overall objective for this project is to develop a technically justifiable, augmented method to retain DA as an acceptable integrity-assessment process for pipeline segments.

Deliverables

- A prioritized list of DA applications from an operator's perspective
- Identification of the strengths, weaknesses, opportunities, and threats for DA use in the highest-priority cases for ECDA
- A set of process enhancements for the selected use cases for ECDA, including augmented inspections and P&M measures, and
- A statistical analysis process for ECDA that will establish confidence, uncertainty, and prediction limits for ECDA assessments.

Benefits

An enhanced DA technique, with technical justification and eventual standard support, would allow operators to comply with regulations for challenging assets such as: vintage pipe that could be damaged by pressure or ILI testing, short tap/tee sections, cased pipe, non-full-bore sections, and other pipeline assets.

Technical Concept & Approach

Specific tasks in this project include:

- **The Development of a Prioritized List of DA Applications**

  This task includes determining the system configurations where use of DA is most critical and where

Congested meter regulator station DA site with crossing situations.

the loss of this option would be of the most detriment. The list will be prioritized by both the type of DA being used (i.e., external corrosion, internal corrosion, and stress corrosion cracking) and also by the physical and operational category of the asset (i.e., station piping and systems, non-full-bore systems, tees, single feeds, vintage pipe, etc.).

- **The Identification of the Strengths, Weaknesses, and Gaps for DA in High-Priority Applications**

  Based on the findings, researchers may select some applications for enhancement development.

- **The Development of Process Augmentations**

  The project team will develop the augmentations to specific ECDA processes. This task will focus on bolstering the current DA practice for the selected applications with additional preliminary data requirements, indirect inspection tool technology and use, changes to current practices such as close interval survey spacing requirements and post-assessment efforts

  Researchers will adapt statistical techniques to be used with ECDA data and allow the operators to apply the results and associate a confidence level and prediction limits to the DA predictions.

Results

A report was released that contained the ECDA literature review. The review includes 53 summaries of standards and peer review papers related to direct assessment, primarily to external corrosion direct assessment. The report also includes information on the ECDA strength/weakness analysis and a key section on opportunities to enhance the ECDA process and data analysis. This section lists 48 opportunities, which are a combination of those expressed in the publications reviewed in the literature search, coupled with those from a sponsor survey.

The opportunities were divided into seven categories:

1. Data and Pre-Assessment
2. Inspection Tools
3. Training
4. Casings, Facilities/Stations, and Pavement
5. Failure Analysis; Corrosion Rates; and Tracking, Trending, and Effectiveness
6. Risk-Based and Probabilistic Analysis, and
7. Accelerate and Simplify.

Congested meter-regulator station DA site with tees, stubs, and tap lines.

The report also includes responses to a sponsor survey and information on ECDA strengths and weaknesses.

In 2020, prior tasks were combined into an outline that now contains the prioritized enhancements.

This project will use a synthetic data set produced as part of OTD 4.20.a *(Safety Impact of Hoop Stress and Percentage of Specific Minimum Yield Stress Boundaries)* to inform the augmented DA method. In that project, a set of closed form model solutions were created, as well as the incorporation of the latest Mat8 Model for crack failures. The new data set will include realistic material, mechanical, and physical properties as well as defect geometries for both wall loss and crack-like defects.

Project activities in 2021 focused on advancing the technical efforts related to developing the augmentations to specific ECDA processes by programming probabilistic calculations for each of the Post-Assessment tallies.

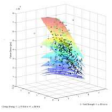
Status

Researchers continue ECDA enhancements and developing a modules-based approach for a DA tools framework.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

MAOP and Materials Verification



This project leverages four significant OTD-sponsored efforts that each addresses a part of the MAOP and materials verification requirements, but currently operate with different software platforms and are not interconnected.

Project Description

The objective for this project is to provide a comprehensive and easy-to-use web-based software solution to assist operators in complying with maximum allowable operating pressure (MAOP) and materials verification requirements for the integrity verification process (IVP) used by gas companies to help maintain safety and reliability.

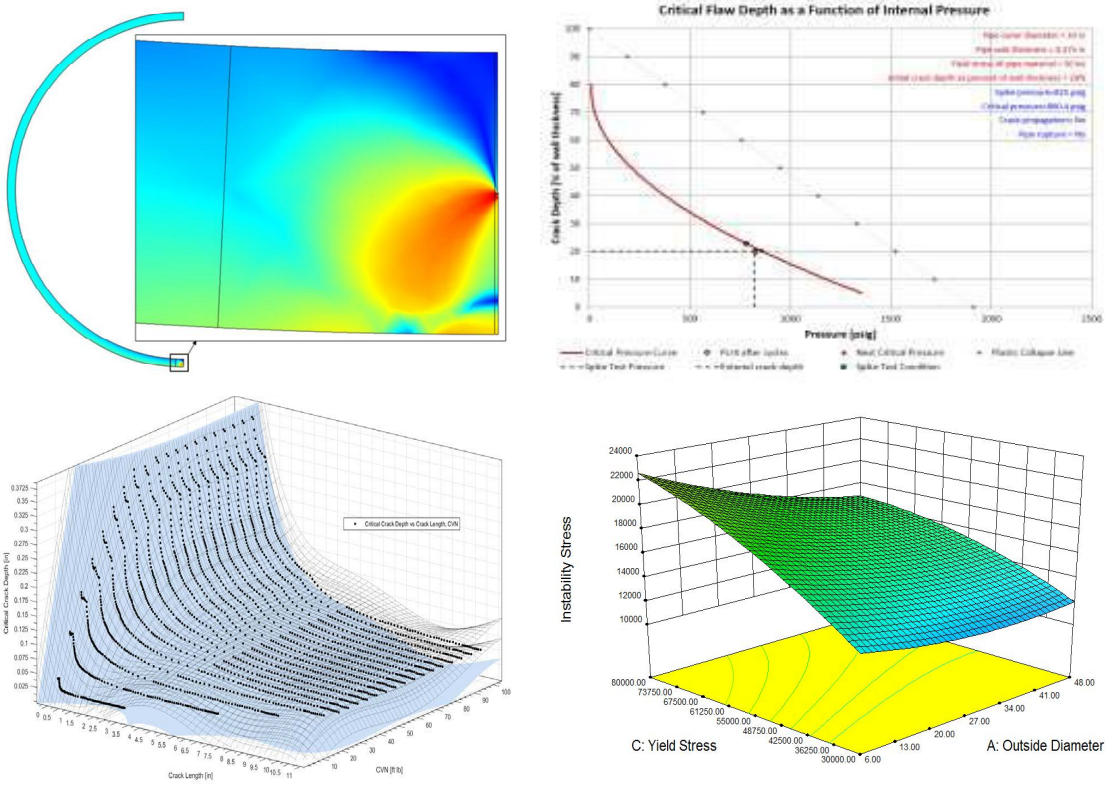
Regulations allow for the use of Engineering Critical Assessments (ECA) in lieu of a hydro-test, de-rating, or pipe replacement. This will also support the use of structured pipe-surface-based non-destructive measurements in lieu of cut-outs and minimize the number of destructive tests when those are absolutely necessary.

This project leverages four significant OTD-sponsored efforts that each addresses a part of the MAOP and materials verification requirements, but currently operate with different software platforms and are not interconnected:

1. ***4.12.b - Correlating Pipeline Operations to Potential Crack Initiation, Growth, and Arrest*** - This project successfully developed and validated the material models necessary to properly model crack initiation in pipeline steels. A detailed calculator using the response surfaces was developed.

2. ***4.13.d - Hydro-Testing Alternative Program*** - This project successfully developed a convenient way to calculate the critical crack axial-flaw sizes and/or non-crack wall loss (e.g., corrosion pitting) that will result in predicted failure at the given pressure.

3. ***4.9.a Leak-Rupture Boundary Determination*** - A study was conducted using incident and laboratory testing data with advanced modeling techniques to calculate the boundary between failure by leak and failure by rupture as a function of the pipe's Specified Minimum Yield Strength.



Information from four key OTD projects is being combined into one easy-to-use format.

4. ***4.14.c Surface Indentation for Material Characterization: Correlation of Surface Properties Based on Vintage*** - The objective of this ongoing project is to develop correlation factors to relate surface properties to bulk material properties for material property validation for pipelines.

Deliverables

The major deliverable for Phase 1 of this project is a vetted software framework that will integrate multiple OTD project models into a single system to assist operators perform MAOP and materials verifications. A Subject-Matter Expert (SME) Group will be established related to IVP and ECA and this group's needs.

Benefits

An integrated solution will provide the benefits from the four foundational OTD projects, but in an easier-to-use, single platform that is also mapped to the most recent, pending code requirements. This approach leverages research that is already completed and focuses the solutions on the newest code-compliance requirements.

Technical Concept & Approach

Specific tasks for this project include**:**

- **Establishing an SME Group for MAOP and Materials Verifications**

  In this task, researchers and sponsors will establish an expert group focused on the use of MAOP and materials verification processes and procedures. The goal is to develop use cases that the sponsor companies will consider to comply with the IVP/ECA process for verifications.

- **Correlating Verification Requirements to the OTD Body of Work and Models**

  In this task, the project team will document the detailed requirements for material verification sampling requirements, including allowed accuracy and margin of errors. Researchers will map the requirements for ECA, materials sampling, fracture mechanics, and metallurgical considerations, toughness assumptions to current model solutions.

- **Developing an Integrated Software Framework**

  The research team will establish requirements and functionality to meet the use cases. Researchers will also establish the output requirements of the software platform to be able to provide a technically justifiable report to support MAOP and materials verification requirements.

Results

In 2018, the project incorporated two actual transmission pipeline field studies with full IVP/ECA implementations. Physical inspection and analysis of the two transmission lines were made with the pilot study operator and service provider. The pilot project ran multiple in-line inspection (ILI) tools and in-the-ditch nondestructive evaluation (NDE) testing to develop the IVP/ECA process and the framework for the associated engineering analysis software. A number of indentations were cut out of the pipe and sent for laboratory analysis.

In 2019, both of the pilot lines completed four ILI runs. The project team will complete the project with the use of data that is now being assembled for another project (4.20.a). This will include realistic material, mechanical, and physical properties as well as defect geometries for both wall loss and crack-like defects.

A set of closed-form model solutions for the ASME B31G modified (wall loss defects) and the Maxey-Folias Leak-Rupture Boundary model were created and checked. Additionally, the latest Mat8 Model for crack-type failures was set up and run. This covers the predicted failure pressures for wall loss and cracks as well as the failure mode (stable leak vs. rupture).

Activity in 2021 focused on designing and developing a modules-based approach for an ECA tools framework. Each module will include a short written description of the module, a flowchart that outlines the steps to execute the module, a checklist, and a Windows-based executable file for pipeline data entry. Additionally, software development of a Windows-based application for data entry of pipeline data for calculations generation occurred.

Status

Ongoing activities include:

- Development of an integrated software framework
- Continued development of additional modules, written descriptions, and checklists that support the ECA framework build out, and
- Drafting the Final Report.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Coating Collaborative

Researchers are establishing a collaborative program for natural gas system operators that tests and evaluates new coatings or existing coatings with reformulations. Ongoing deliverables include a recurring process of coating selection, testing, and reporting in following phases.

Project Description

This project involves the establishment of a collaborative program for natural gas system operators that tests and evaluates new coatings or existing coatings with reformulations.

The AGA Corrosion Control Committee supports this effort and has agreed to act as a technical sounding board for the collaborative program.

The goal of the collaborative is to independently and objectively evaluate coatings for the natural gas industry – specifically, for buried and aboveground pipeline and distribution systems.

Each year, a set of coatings will be selected and tested, and performance results will be provided as a set of objective, third-party information, similar to a *Consumer Reports* report with clear, concise test results.

Deliverables

The main deliverable for the first year of the collaborative is an agreed upon set of laboratory and field testing protocols and an associated testing roadmap/plan.

After the first year, the ongoing deliverables for this program will be a recurring process of coating selection, testing, and reporting in following phases.

Benefits

The goals of the coatings collaborative are to:

- **Reduce Risks**

  This program provides third-party, independent testing of coating performance for specification development, avoiding the specification of a coating system that may result in system failures and costly replacements, repairs, or incidents.

- **Implementable Results**

  Efforts will be made to ensure that the coating testing will be timely and meaningful; with results organized so end users can apply and implement them efficiently.

- **Collaborative Efficiency**

  Individual sponsors can submit requests for particular coating systems that would then be put into the program cycle for testing.

Technical Concept & Approach

The focus of this project is placed on existing, new, and improved coatings, such as:

- Two-part liquid epoxies for buried and aboveground assets
- Fusion-bonded epoxy coatings
- Quick-curing fiberglass fabric wraps
- Bore and horizontal directional drilling coatings, abrasion-resistant overlays, and polymer concretes
- Wax and petrolatum tapes
- Mastic-based and modern visco-elastic polyolefin coatings soil-to-air transition coatings, e.g. at risers
- Vault application coatings
- Keyhole maintenance and installation coatings
- Composite-based coatings and tape wraps, and
- Other coatings submitted by the collaborative membership.

Coating systems will be applied to full-size gas pipe with girth welds vs. coupon testing alone.

Testing will include the key performance metrics important to the industry, such as testing for:

- Adhesion
- Impact resistance
- Abrasion resistance
- Cathodic-disbondment resistance
- Cyclical corrosion (salt-fog)
- UV resistance (aboveground applications), and
- Other, application-specific measures.

These shorter, laboratory-based tests will be supplemented with burial testing to correlate short- to long-term testing results.

The project team will draft a laboratory- and field-testing plan. Investigators will estimate how many coatings will be tested each year and at what cost. Each year, a set of coatings will be selected and tested, and performance results will be provided.

Results

In 2019, the project team began a review of related projects completed over the previous 10 years. A product matrix was created and populated with the prior testing results. The team also created a draft of the typical and extended/specialized coating test methods, will continue to add to this list, and then prioritize and categorize the tests in groups applicable for specific generic coating classes.

The team also reviewed coating tests and the required sample numbers and sizes, durations, and approximate costs per test.

In 2020, the research team developed a product matrix with 44 product/coating systems, detailing color, surface preparation requirements, application requirements, potential life, and other features. The team also continued to develop a list of coating tests to prioritize and is researching the required sample numbers and sizes, durations, and approximate costs per test.

Tests are organized by groups related to corrosion, mechanical coating strength, disbondment, exposure, etc., and listed the test method, use case service environment that the tests are applicable to, priority of tests, and other parameters.

In 2021, a report was prepared to establish an independent coatings collaborative testing program. This program will provide a third-party, independent testing of coating performance for specification development and avoid specifying a coating system that may result in system failures and costly replacements, repairs, or incidents. This project's objective establishes a framework to execute a program collaborative for operators that tests and evaluates new coatings or existing coatings with re-formulations. Each year (or on an as needed basis), a set of coatings will be selected and tested. Using this framework, the project team will administer the collaborative so individual sponsors can submit requests for particular coating systems that would then be put into the program cycle for testing.

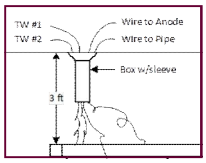
Status

The Coatings Collaborative Program Framework report was issued in July 2021.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Remote Monitoring of Pipe-to-Soil Readings, Equipment Identification, and Evaluation



Researchers are identifying and evaluating easy-to-deploy remote options that are available for measuring galvanic cathodic protection (CP) in the natural gas industry. Manufacturers of corrosion-protection equipment are being engaged in identification and development efforts to review equipment, materials, and software to obtain pipe-to-soil readings accurately and remotely.

Project Description

Obtaining pipe-to-soil readings is a federal requirement that ensures the safety of the gas distribution system by measuring the cathodic protection (CP) applied to steel pipelines to determine if corrective action is required to prevent corrosion.

The ability to remotely monitor the cathodic protection of a gas distribution system offers a variety of advantages to a gas system operator. In this project, a research team will identify and evaluate easy-to-deploy remote monitoring devices for measuring levels of galvanic CP in gas distribution systems. The evaluation will include the CP devices, associated equipment and materials (i.e., reference cells), and the software platform for remote monitoring of the pipe-to-soil potential readings.

Researchers are identifying and evaluating remote pipe-to-soil options that are available within the natural gas industry that could be easily installed on a gas service pipe. Two vendors have agreed to supply equipment. These two vendors provide a turnkey system of components that are completely installed below grade and can be used on service pipes. The testing for these two vendors will be performed at a pipe field and will be using a cellular-based communications network to confirm the remote pipe-to-soil readings.

Deliverables

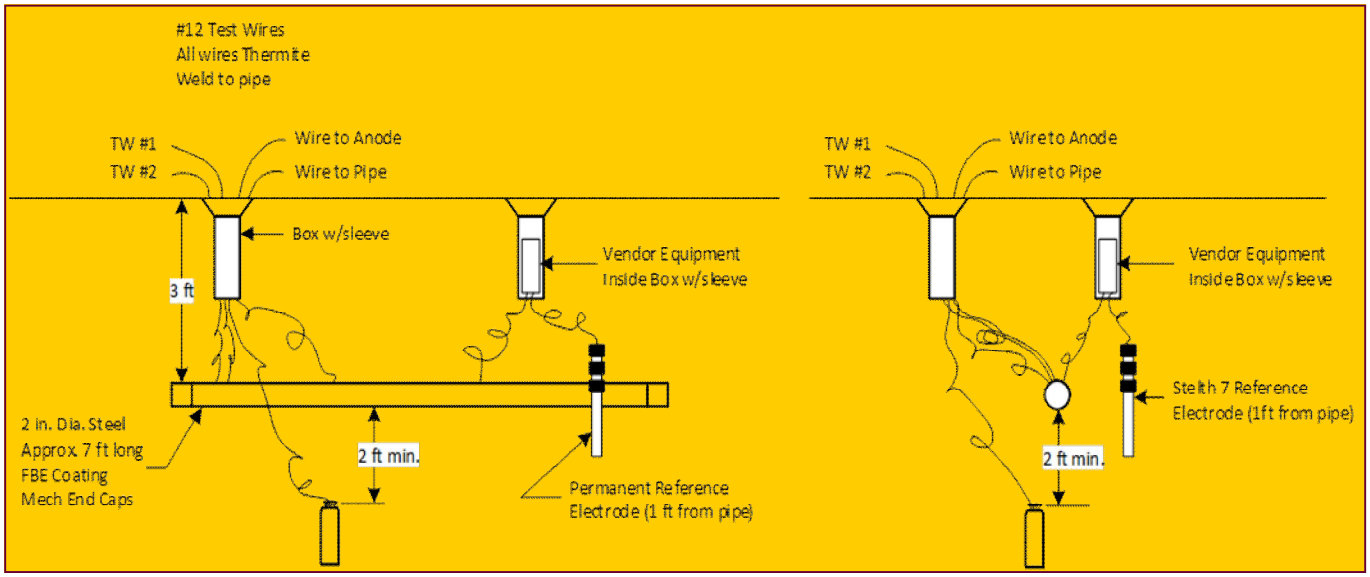
The deliverables for this project will include:

- A test plan and field study of the vendors equipment, including software and communications over a cellular network, and
- A Final Report detailing the technical specifications and the field testing for each of the devices that were tested.

Benefits

Obtaining routine pipe-to-soil readings on steel distribution systems throughout an entire service territory is a time-consuming and costly expense for utilities. Also, the number of personnel specializing in performing this type of work effectively and efficiently is decreasing across the industry.

Monitoring widespread pipe-to-soil measurements on a more frequent basis would be the best first-line of defense in identifying areas of a pipeline system with weak or inadequate corrosion mitigation. Frequent data to allow for trending analysis is a powerful tool for CP specialists to use in identifying changes in protection levels throughout a system.



The ability to remotely monitor the CP of a gas distribution system offers the following advantages to a gas system operator:

- Improves safety by reducing human error related to improper pipe-to-soil readings by employees
- Improves compliance by alerting and providing needed information in a timely manner
- Provides the ability to have readings more frequently and readily available to allow for trending analysis for future estimating and planning, and
- Will reduce or potentially eliminate the total number of labor hours required to perform pipe-to-soil readings and to determine corrosion-related corrective action workloads

Technical Concept & Approach

Specific tasks include:

- **Identification of Existing Easy-to-Use Turnkey Remote Pipe-to-Soil Vendors**

  This task includes project kick-off activities, identification of CP telemetry needs, sponsor interactions, needs analysis, tasks preparation, and other related activities.

- **Identification and Evaluation of Available CP Devices**

  In this task, researchers will identify and evaluate current CP telemetry devices available in the market. The evaluation will include the CP device operating features, associated equipment and materials needed, and the software requirements for transmitting and receiving the remote readings.

- **Field Testing of CP Devices and Software Applications**

  This task will include installing the selected CP devices on different-sized steel piping, with different types of coatings, levels of anode protection, and types of soils. The project team will record regular readings remotely and manually for comparison.

Results

Activities for this project included identification of the project team, conducting a project kick-off call with sponsors, performing a search of existing products, and speaking with industry subject-matter experts on available products. Two vendors were chosen and their equipment has been installed at the Gas Technology Institute pipe field in Des Plaines, IL.

Status

- Equipment from both vendors has been installed at the pipe field
- Implementation of the test plan to the end of the project (potential testing of an AMI network) is ongoing
- Continuous field verification of remote data is being obtained
- Preparation of the Final report with test results is under way.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Safety Impact of Hoop Stress and Percentage of Specific Minimum Yield Stress Boundaries

Researchers completed a knowledge-based study on 20%-30% Specified Minimum Yield Strength (SMYS) segments, including leak vs. rupture considerations and failure modes. This represents the culmination of a comprehensive effort to provide a simple set of criteria for use by operators and regulators.

Project Description

This project focused on a study on low-strain steel gas pipe to determine whether specific pipe segments operating between 20%-30% SMYS (Specific Minimum Yield Stress) are safely operating as distribution lines or should be reclassified as transmission lines. The study indicates that, if proven safe, steel transmission lines operating between 20%-30% SMYS can be safely transferred into the distribution classification and safely operated.

This project provides information to help ensure the criteria for transition between distribution and transmission integrity management programs maintains a consistent level of safety. If appropriate, the outcomes can also be considered for new/updated language in the ASME B31.8 family of standards.

For this project, researchers completed a knowledge-based study to:

- Document definitions for natural gas transmission and distribution lines
- Complete an in-depth literature review
- Establish safety considerations for new vs. existing systems related to Distribution Integrity Management Programs (DIMP) and Transmission Integrity Management Programs
- Review safety/integrity implications from classifying transmission-to-distribution, and
- Document in-service history/incidents and system attributes.

Deliverable

Deliverables for this project include:

- A regulatory definition review
- In-depth literature search
- In-service and incident history analysis
- A sensitivity study of pipeline features/parameters, and
- A report on safety considerations for segment classifications.

Benefits

The study findings support a technical commentary to determine if, and when, the 20%-30% SMYS boundaries play a genuine role in setting the division between distribution and transmission operations and safety activities.

Large-diameter lap seam spiral-welded pipe. (Image courtesy of K. Leewis.)

The databases will be turned over to the U.S. Department of Transportations (DOT) Pipelines and Hazardous Materials Safety Administration (PHMSA) for placement on a publicly available website. Additionally, the project database can be maintained as a reference data source if anticipated users fund the maintenance of a cloud-based data-site service on an ongoing basis.

Technical Concept & Approach

The approach taken in this project leverages systematic processes and an extensive range of failure calculations, underpinned by deep, rigorous statistical analyses, to achieve and confirm the project results.

The team collected and analyzed in-service pipe history, including the pipe vintage, seam type, diameter, and mileage. The team also confirmed the leak/rupture history of legacy mill pipe production by diameter, steel grade, and seam type. National Transportation Safety Board reports and PHMSA incident data were reviewed for pipeline leak and rupture events.

The project team clarified and organized how older rules, based on vintage-to-modern pipe performance, provided an engineering rational to help designers, operators, and regulators understand the philosophy of the safety rules behind the earliest codes.

A key safety consideration is the leak vs. rupture boundary, which is heavily influenced by the shape/ aspect of a flaw, normal to the load direction. Those with longer and deeper features have a higher probability of failure by rupture. This effort defines limiting sizes of imperfections and flaws between new and old/ vintage pipe with the understanding that new pipe will generally be cleaner and safer for the same flaw size.

Results

This study represents the culmination of a comprehensive effort to provide a simple set of criteria for use by operators and regulators for natural gas distribution and transmission systems.

A report provides a description of vintage pipe-fracture properties for pipe produced before 1970 and can be used to estimate toughness values in these earlier years. A summary of pipe-mill seam performance by decade of manufacture is presented, which identifies mills with greater incidents of field hydrotest failures. An estimation of various steel production-to-pipe making technologies was used to estimate a de-rating factor by decade of manufacture and estimate an expected rate of future reportable incidents by decade of manufacture.

A methodology was chosen to predict failure as a leak or a rupture. Additionally, researchers reviewed the leak/rupture boundary development history and boundary visualization, including discussion of related alternatives.

The report addresses several methods to estimate the plastic collapse for general wall loss (such as corrosion), and reviews the approaches from simplest to most complex, including the various two-parameter (depth and length) methods.

The project team compiled and reviewed the incident data and reports for natural gas transmission and hazardous liquid pipelines from 1970 to 2019. The investigation looked at the various characteristics and attributes of these failures, such as in-service history, pipe age, seam type, grade, diameter, wall thickness, mileage, and the textual narratives of the incidents to gain further insight into their primary causes.

A parametric study was performed on five pipe attributes and three operation parameters defined as accident pressure, failure location (pipe vs. weld), and root-cause.

A Design of Experiments (DOE) for steel gas piping systems was developed. This included extensive considerations from failure databases, annual reports by operators, historical experience, and published literature which can be found in the references section of the Final Report. After the DOE was constructed, the configurations were used to calculate the associated failure and boundary values. The distribution of failure mode categories was evaluated across the entire DOE and mapped to the independent variables in a sensitivity analysis. Predictive margins were analyzed using the independent variables and plotting the sensitivity of the failure mode category to these combinations. A framework was developed to take these inputs and classify them into three basic risk categories given a combination of operating conditions, pipe attributes, and defect type and geometry.

A regulatory review was conducted and a summary completed of the definitions in the code and regulation as well as requirements pertaining to low-stress pipelines to assist in locating applicable segments and understanding their peculiarities.

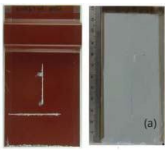
Status

This project is complete. A Final Report was issued in March 2021.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Self-Healing Coatings – Development and Laboratory Testing for Gas Utility Application



Research is under way to test a market-ready self-healing pipe coating and a self-inhibiting coating. Investigators will compare corrosion resistance, mechanical properties, and preparation requirements in the laboratory to determine relative cost differences.

Project Description

Natural gas utilities have long invested in solutions to prevent the causes of coating failures, but few have addressed the underlying problem of stopping corrosion once the coating is breached. A review of nanotechnology found that self-healing coatings employing microencapsulation technology may have the potential to restore a failure point and prevent further corrosion.

Self-healing coatings have been available for years, but most require some sort of external activation (e.g., heat or a solvent). Self-passivating coatings using sacrificial zinc are in the market and are applied by some gas utilities; however, most utilities dislike the thickness, surface preparation, and cost requirements.

This current effort involves tests of hydrophobic topcoats for aboveground assets to prevent the permeation of water on sites with easily pooling water.

Applications already developed are for more extreme environments in aerospace, turbines, and cooling towers. However, manufacturers are interesting in expanding into the utility market, noting that their products can transfer easily, even with cathodic protection.

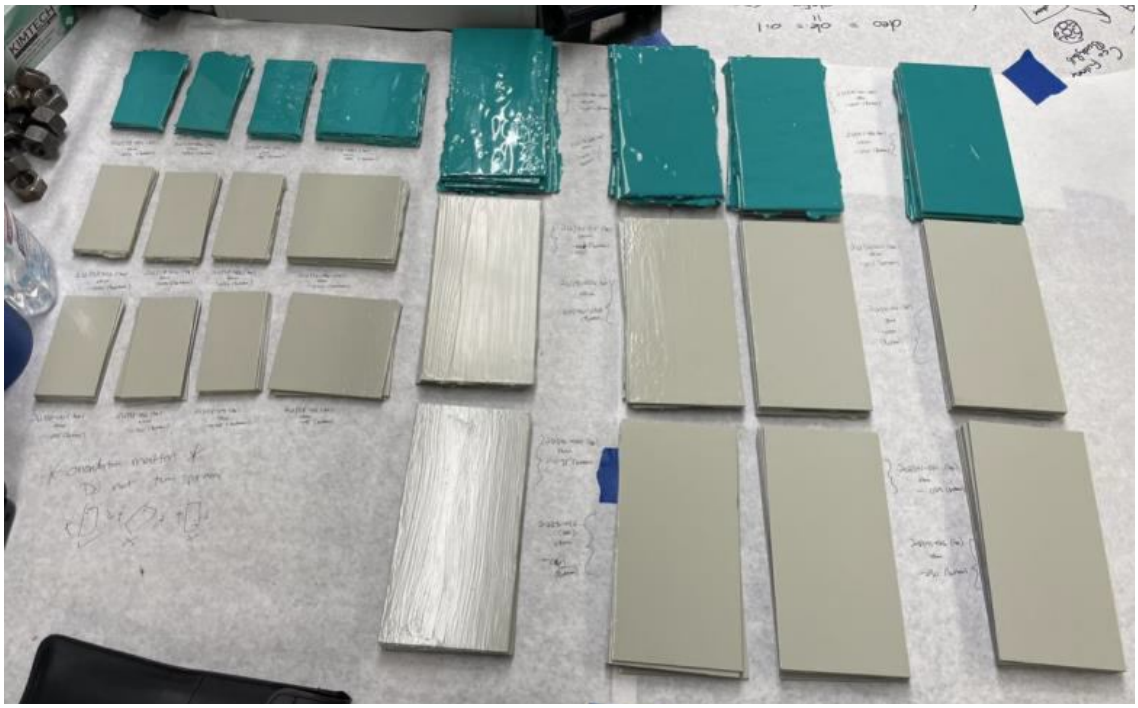
The benefits are significant, but utilities must first confirm performance and coating integrity for their specific applications.

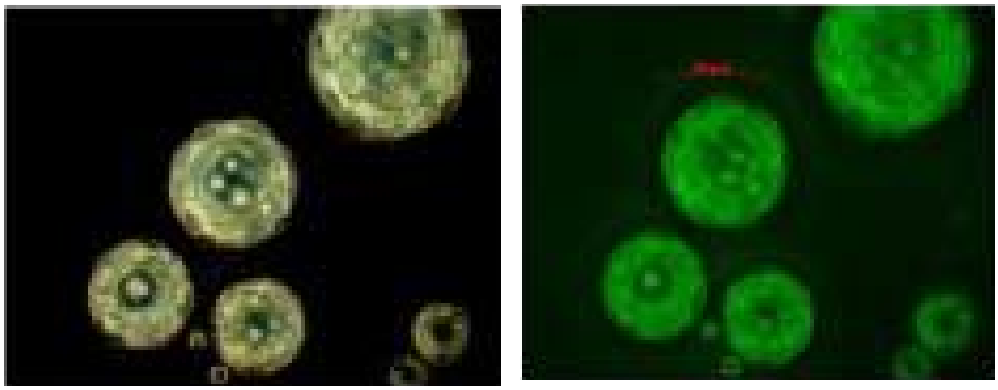
Deliverable

The project deliverable will be an evaluation of self-healing and self-inhibiting coatings in terms corrosion resistance (creep), mechanical integrity, cost, and preparation requirements. If results are promising, investigators will recommend field studies for a Phase 2 evaluation.

Benefits

Corrosion costs gas utilities $5 billion each year and is the culprit of many gas leaks and service shutoffs. Even the latest coatings with high corrosion resistance and adhesion will peel once the coating layer has been breached. The ability to mend exposed metal without active personnel would be a breakthrough technology for the gas industry.





Smart corrosion-detector beads fluoresce a specific wavelength of light when in the presence of rust.

Technical Concept & Approach

In this project, testing laboratories will validate performance, investigate changes in mechanical integrity, compare surface-preparation requirements, and the determine relative costs of self-healing coating.

Specific tasks include:

- **Selecting Coating Formulators**

  The project team and sponsors will decide on the ideal coating application and the corresponding coating specifications.

- **Determining Coating Formulas**

  The project team will approach coating formulators with the specifications of the intended application and develop the test matrix using software that applies design-of-experiment methodology.

- **Developing Coating and Assessing Costs**

  If the companies determine the expected formulations can meet applications, then researchers will contract to develop samples. Upon completion, the team will assess relative costs of the coating.

- **Laboratory Performance Tests**

  Researchers will test the performance of the self-healing coatings by measuring corrosion creep against a representative control. Mechanical properties (e.g., hardness, abrasion resistance, adhesion, chip resistance, and cathodic disbondment) will also be investigated.

Results

In 2020, the project team confirmed participation from two self-healing additive providers and submitted a sponsor survey. The survey asks a series of technical questions that determine the ideal use case for self-healing coatings and minimum specifications for coating application and performance. Risers (soil-to-air transition zone) are the leading use case.

The self-healing coating use case was narrowed to aboveground applications with liquid polyurethane or epoxy coatings to minimize project risks. The self-healing additive providers are more experienced with aboveground applications; liquid polyurethane/epoxy present larger markets, and the relevant coating performance tests are more affordable. Findings from this study will decide if and how the project team will expand into belowground use cases.

The project team is tailoring the planned coating performance tests and formulation approach towards a variety of failure modes (e.g., edge, cyclical, poor abrasion, etc.). The failure modes translated into the coating performance tests (e.g., corrosion, adhesion, hardness, and chip-resistance testing).

Coating formulas to test were finalized, a laboratory specimen for coating was selected, coating application and testing procedures were draft, and supplies purchased.

A test plan was developed that divides into tests for two-layered coating systems and single-layered coating systems. The primer coating systems will be tested for adhesion to the substrate, cure, and hardness. The primer with topcoat systems will be tested for scribed, cyclical corrosion, UV condensation, and adhesion.

In 2021, researchers purchased all supplies and services necessary for the project, finalized all the testing protocols, prepared the self-healing coating, and began coating the specimens. The project is currently paused due to a three-month shipment delay of one of the coatings

Status

Researchers are waiting to receive the last coating product for application. Technicians will coat primer and topcoats onto the second side of specimens.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

CONSTRUCTION/ INFRASTRUCTURE TECHNIQUES

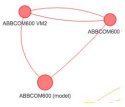
Addressing issues often beyond the traditional areas, this research involves the development of tools and techniques for metering, gas shutoff, remote monitoring, cathodic protection, data collection, and other applications.

Developed technologies are subjected to a regimen of laboratory and field evaluations to ensure their safety and efficiency.

Efforts include projects to enhance and broaden the knowledge base for plastic pipe materials, virtual reality training, development of technology for remote service abandonment without excavation, cybersecurity, addressing gas odor fade, and re-development of underground piercing tools.

.

Cybersecurity Collaborative



This project involves the development of a multi-year collaborative program between natural gas distribution companies and the U.S. Department of Homeland Security (DHS) to address natural gas industry high-priority cybersecurity issues.

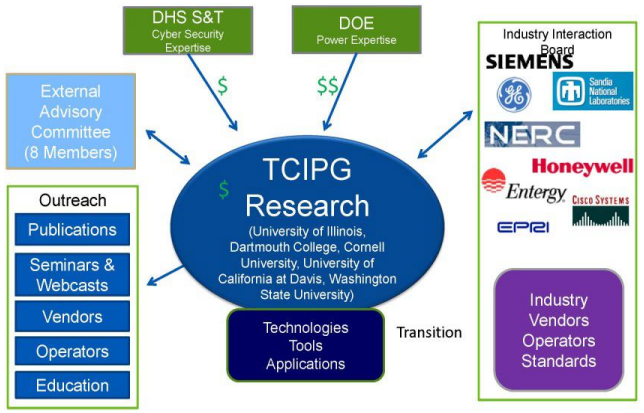
Project Description

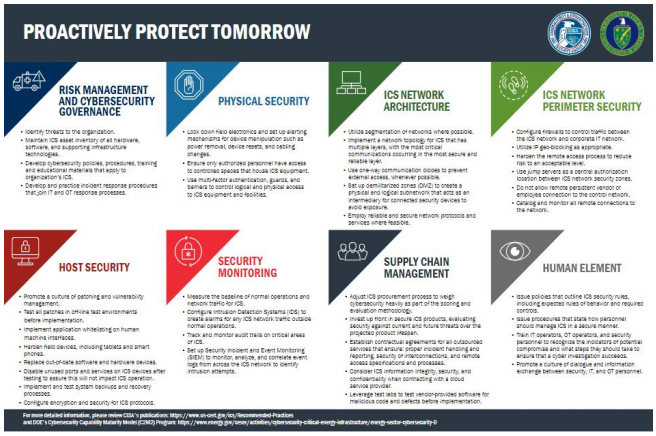
This multi-year Cybersecurity Collaborative between natural gas distribution companies and the U.S. Department of Homeland Security (DHS) addresses the high-priority cybersecurity issues through an outreach and education process and a technology evaluation and transfer initiative. This combined emphasis is intended to reduce risk and diminish cyber-attack threat exposure, intellectual property theft, and system operations disruption or damage.

Program results may be used by operators to educate internal and contracted personnel about cybersecurity, as well as evaluate and, where appropriate, implement state-of-the-art technologies focused on the prevention, detection, and mitigation of cyber threats.

Prominent activities and initiatives undertaken under Phases 1 and 2 to mitigate cyber-attacks include:

- Promoting collaboration among cybersecurity-focused organizations, such as the U.S. Department of Energy, the National Institute of Standards and Technology, the American Gas Association, and Colorado Energy Institute.
- Curating a team cybersecurity reference site which – when combined with quarterly meetings, educational field visits, and tabletop exercises – provides a forum to identify needs, share concerns, and discuss technology gaps, and
- Assessing cybersecurity technology effectiveness, evaluating methodologies to protect field-based technology, and identifying best practices.





Workshops provide a variety of critical information for improving the safety of gas distribution systems.

Deliverables

The deliverables are expected to include:

- An outreach and education program
- A vetted, prioritized, brief list of technologies and supporting material for transfer to utility operations
- One or more technologies identified and vetted by DHS transitioned to practice
- A cybersecurity technology "road-map"
- One or more projects addressed within each of the areas of Model Assessment and Application, "Technology to Manage Technology," and Common Practices.
- A test bed for modeling control systems, SCADA monitoring, detection/correlation, and failure scenarios, and
- The development of Best Practices.

Benefits

This emphasis is designed to provide a reduction in the risk and exposure to the threat of cyber-attacks and malicious activity directed at the theft of intellectual property or disruption/damage to system operations.

Technical Concept & Approach

An OTD-sponsored needs-identification workshop was conducted to set the strategy and technical approach for the Collaborative. High-priority areas were identified as 1) asset management of devices and systems capable of providing a pathway for cyber-attack and 2) detection of a cyber-attack and/or malicious activity. Research priorities were revisited at all subsequent quarterly meetings and the strategy was realigned as appropriate

Results

In 2018, Pacific Northwest National Laboratory was contracted to support the Cybersecurity Collaborative through consultative subject matter expertise, execute technology tests for development of best practices, secure operation of natural gas distribution, and provide access to and manage testbed and other test resources to enable collaborative test execution. Additionally, in-person meetings were held in Richland, WA, and McLean, VA. The latter location was the site of a Collaborative-executed Tabletop Exercise focused on operations response to real-world cyber scenarios.

In 2019, project execution continued on access control, failure scenarios, and cyber-analytics dashboards for operations technology. Additionally, DHS provided updates regarding ongoing agency reorganization initiatives and statuses for in-process cybersecurity efforts.

Also, the Collaborative participated in the first-ever Joint Consortium Meeting for Critical Infrastructure sponsored by the DHS. The invitation-only meeting's purpose was to connect government and partners from various industries to discuss common threats, challenges, and successes while learning about the mission and strategy of government agencies to help secure critical infrastructure.

In 2020, the project team facilitated a webinar to discuss a potential solution that may be leveraged to address the security needs of natural gas utilities.

An interactive two-day workshop was held to help drive solidifying sponsors' functional and data requirements. The primary focal point of the meeting was to elicit a set of business objectives and requirements for cyber-security monitoring of a natural gas distribution network. Findings from the workshop were presented at the September quarterly meeting. Additionally, updates were provided on federal agencies' activities and available information.

The team and sponsors developed consensus language for a Collaborative-authored communication aimed at engaging device manufacturers to develop solutions that fully support natural gas operational technology situational awareness.

In 2021, research on potentially applicable commercial situational-awareness tools/technologies continued and two additional solutions were identified and added to the previously drafted list.

The results of surveys completed by OTD organizations for a cyber-enabled impact demonstration project were reviewed and detailed notes presented.

Status

Phase 2 of the Cybersecurity Collaborative was brought to a close at the end of the third quarter of 2021. Phase 3 of the Collaborative, which establishes a Cybersecurity Working Group, focused on developing a prioritized roadmap of research initiatives, was kicked-off in the fourth quarter of 2021.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Alternative Caps for PE Service Tees

The objective of this project is to design an alternative cap for polyethylene service tees that will reduce the possibility of nuisance leaks from cross-threading, over-tightening, and improper O-ring installation.

Project Description

Polyethylene (PE) service tees that act as the connection point to a utility's main line require a cap because a portion of the main is bored open after the service tee is fused to it. In operation, a boring tool enters the fitting through the top of the tee. After the hole is drilled through the main, the tee is covered by a threaded cap and an O-ring is compressed to form a leak-tight seal.

In this project, researchers investigated alternative caps and fusing methods. The research team explored options with sponsors and service-tee manufacturers, culminating with the development of a requirements document along with alternative conceptual designs.

The overall objective is to design an alternative cap for PE service tees that will reduce the possibility of nuisance leaks from cross-threading, over-tightening, and improper O-ring installation.

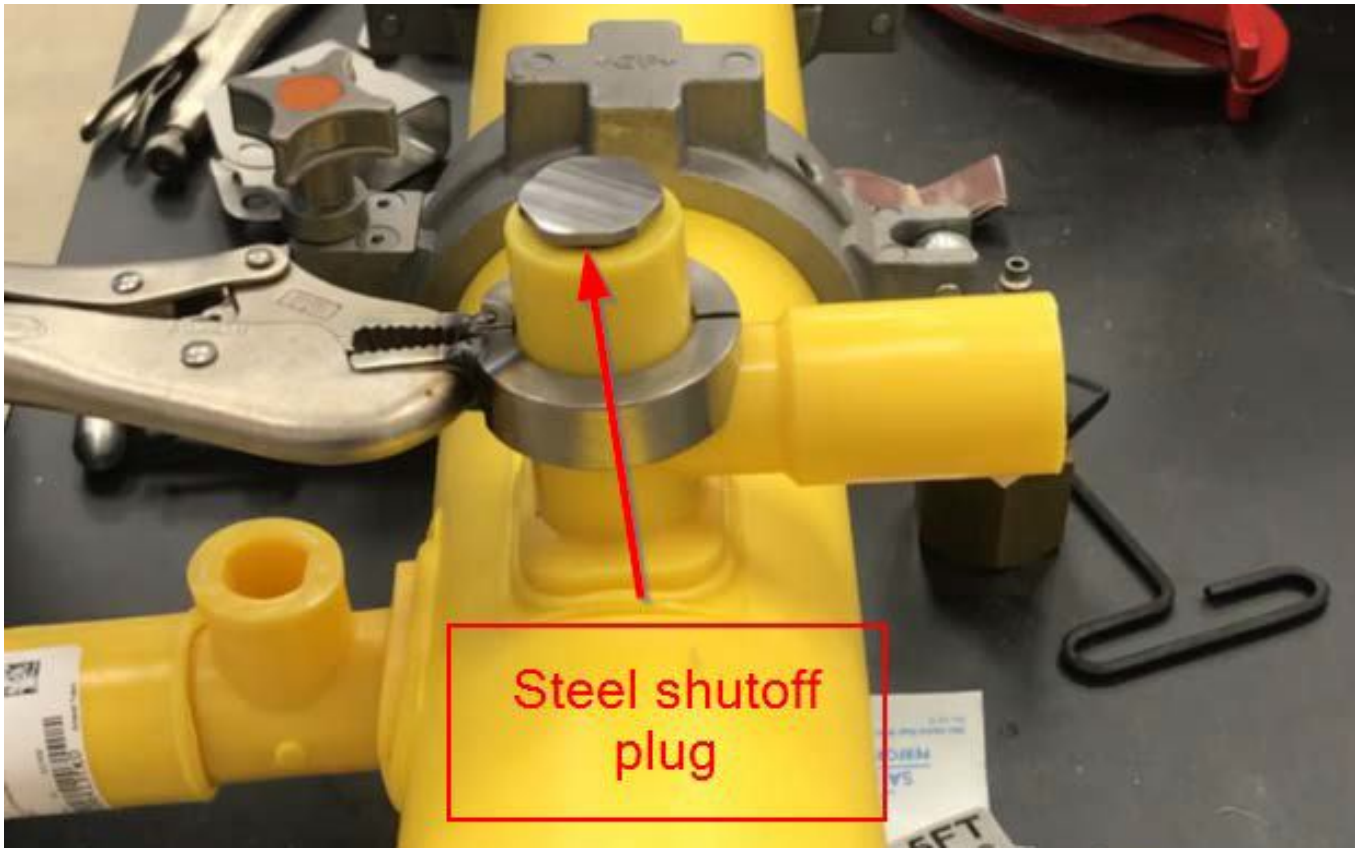
Deliverables

The deliverables for this project include conceptual designs for an alternative service tee cap and fitting specifications based on the requirements of North American gas distribution companies.

Benefits

PE service-tee nuisance leaks are a major concern for gas utilities because they usually require excavation and can be expensive to fix.

A major cause of service-tee leaks is a faulty cap, which can be accidentally cross-threaded or over-tightened during installation or have an O-ring installed in the wrong position, which eventually leads to the cap losing its leak-tight seal.



Main thread steel shutoff plug punched into the special threaded punch.

Creating an alternative cap that is more reliable than the current threaded caps, such as a fusible-type cap, could save money and time because of the reduced amount of nuisance leaks.

Technical Concept & Approach

Initial tasks in this project included a sponsor survey to identify the needs and applications for a fusible cap device. A summary of sponsor requirements was compiled. Based on the needs and requirements, the project team developed conceptual alternative cap designs.

Project representatives contacted various tapping tee manufacturers to determine interest in developing alternative caps for their tapping tees. A method of connection with a fusible cap for tapping tees was investigated. A cap with more robust threads to prevent cross-threading was also studied.

Results

Researchers found three possible options for alternative PE caps: an improved mechanical cap, a socket fusion cap, and an electrofusion cap. An improved mechanical cap would address the issues with current mechanical caps. For operators that prefer a fusible cap, either socket fusion or electrofusion caps are possible, the former being simpler to design and manufacture. In both fusible cases, the tower of the respective tapping-tee may need modification or machining/scraping tools may need to be developed. Additionally, both fusible-cap types would require a method to stop blow-by around the cutter.

One manufacturer is developing two types of caps (an electrofusion cap and a socket fusion cap), but is much further along on the socket-fusion solution. The company has made some aluminum cavities to remove the tower threads on the service tee and should have some molded samples soon to test the theory. The first round of cap fusion tests at 100 psig pressure were completed, followed by 1,000-hour hydrostatic pressure testing. The company is also developing coil designs for the electrofusion cap and evaluating the changes required for the tee body.

In 2019, the manufacturer molded additional fittings and refined the procedure for installing socket-fused caps following the tapping operation into a live main. A custom mold cavity was built to produce a service tee fitting without the tower threads for a standard threaded cap.

An electrofusion cap was developed by the manufacturer's sister company in Switzerland. The cap is designed to permanently seal the tower of a tapping tee after the line is tapped.

In 2020, several concepts were explored:

1. Threads removed from top of tower to create a fusion zone
2. Thread length shortened to create a fusion zone at the bottom of the tower, and
3. An electrofusion coil placed within the pitch of thread.

Option 3 seems to be the best and least invasive design as it would work with existing service tee fittings. It would also be the lowest cost to implement.

Based on sponsor feedback, the preferred solutions are new fusible caps for the installation of electrofusion and socket-fusion saddle fitting types.

Early testing showed there could be a possibility of failure of the socket fusion if heating parameters are not strictly followed. Excessive heating could cause the sealing device to leak, allowing pressurized gas into the cap and create wormhole leaks through the molten fusion area.

Several different concepts for building the electrofusion cap were investigated. The most universal concept would be to build a cap that screws onto existing service tees. This would allow sealing of the tower with the current method of two O-rings and fusing of the threads to create the permanent connection. This method would allow both a standard and electrofusion cap. No changes to the standard product would be required.

In 2021, project activities included corresponding with one of the project sponsors to gauge interest in evaluating the heat-fusion cap and exploring the possibility of collaborating with another vendor.

Any option is available to pursue as long as there is volume to justify development costs.

Status

The project is on hold pending further discussions with the sponsors and the manufacturer.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Evaluation of the ORFEUS Look-Ahead Technology for Horizontal Directional Drilling

Researchers are developing an obstacle-location technology for use in horizontal directional drilling (HDD) applications. ORFEUS (Optimized Radar to Find Every Utility in the Street) is an effort aimed at developing a safe, cost-effective "look-ahead" system for HDD equipment.

Project Description

The ORFEUS effort is conducted by a collaborative organization of multiple companies to develop a prototype obstacle-detection system for HDD operations. This project seeks to bring forward a commercially viable product for identifying obstacles in and around the path of a HDD drill rig.

The goal of the project is to improve the ORFEUS (Optimized Radar to Find Every Utility in the Street) obstacle-detection technology by: making improvements to the bore head radar; software enhancements to improve the user interface; improvements in the communications to the drill head, enabling the lengthening of the total drill length; performing system validations and market launch preparations; and conducting operational field tests.

As part of a previous project, an ORFEUS system prototype was demonstrated in operational field trials in Germany, France, and Slovenia. In a 2017 trial at a U.S. utility training facility, a test site was built and the system detected the test objects buried there, including boulders. In this project, field evaluations will be continued with ORFEUS an increasingly demanding program of trials to demonstrate continual successful operations.

Deliverables

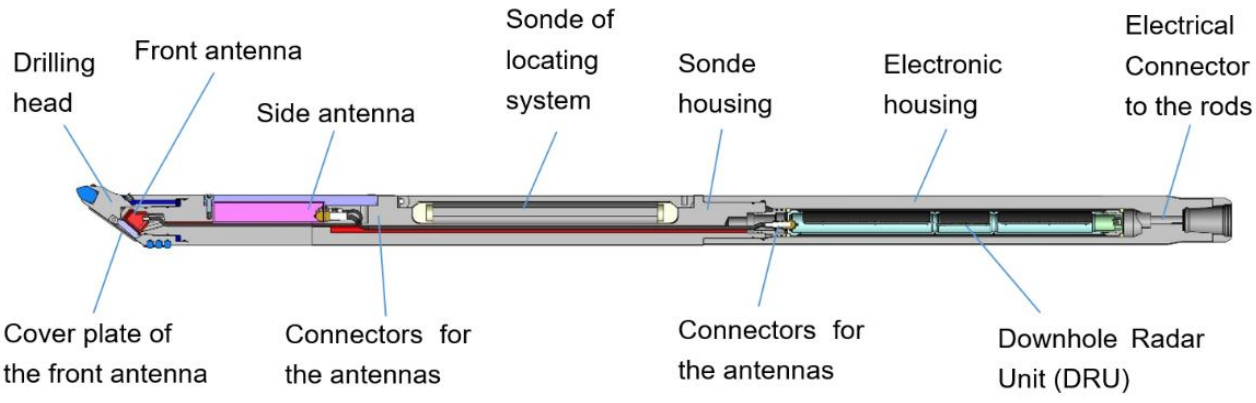
The deliverables for this project include field demonstrations, reporting of demonstration results, and a Final Report.

Benefits

The continual growth of using HDD operations has raised the need to reduce the threat of damage to other underground infrastructure, especially unknown sewer mains and laterals. HDD offers significant benefits for urban environments by minimizing the disruption caused by the installation of underground utility infrastructure such as natural gas pipelines.

Operating within the drill head of HDD systems, ORFEUS provides real-time obstacle detection needed to increase the safety margins of HDD operations to allow its use in the widest possible range of conditions.

This technology has the potential to markedly increase safety for homeowners, utility companies, and contractors from cross bore incidents. This technology can also enhance the installations of distribution gas lines in difficult areas where other utilities may intersect.



Assembly of the downhole equipment.

Technical Concept & Approach

Specific tasks include development of:

- **HDD Bore-Head Radar**

  Activities in this task benefit from the outcomes of the previous ORFEUS research and focus on those aspects that were found requiring a further effort to produce a commercially viable product.

- **Communications Links**

  The objective of this task is to improve and production-engineer the modem and power modules, both in the cab and at the drill head based upon the existing design and digital signal processor architecture enhanced by using information gained from the previous project's field trials.

- **System Software**

  This task addresses the development of the software for the HDD radar system. Data analysis on field demonstrations of the previous system had successfully proven the capability of target recognition in different soil conditions; however, some further developments are required to make this technology fully exploitable in a commercial system.

- **System Validation / Market Launch Preparation**

  Commercializing ORFEUS technology as soon as practically possible is the consortium's firm intention and the validation of the system by means of operational system trials is a key part of the necessary preparations. Testing will evaluate the system's ability to detect various buried underground utilities commonly found in roadway right of ways.

- **Operational Tests**

  A minimum of six demanding, graded, operational demonstration trials to confirm the operational reliability and readiness of the system will take place. The sites will be selected by a panel of end users, taking into account the soil conditions and buried infrastructure configuration.

Results

Initially, a field trial of the ORFEUS system was conducted in 2017 on a purposely built testing area including several targets (utilities and boulders). Results from the trial confirmed the performance of the ORFEUS system and the suitability of the technology for preventing the striking of utilities and other objects when drilling through the ground. Specifically, a selection of non-conductive and metallic pipes with different diameters with respect to the expected drilling path were used for the trial.

In 2019, an angular sensor prototype was built, showing very promising results. In the current project, the angular sensor is being re-designed because some fundamental electronic components are discontinued, mechanical constraints are changed, and to be compliant with the final requirements.

In 2021, OTD executed a subcontract to take on the liabilities as the main subcontractors.

Main activities concerned the accurate definition of the connections between the subsystems in order to facilitate the assembly.

The small space available for hosting that front antenna constrains the height of the electronic boards for the microwave source and receiver. Thus, a whole redesign of such components was required and prototypes were made available for testing. Main innovation introduced in the design concerns the splitting of the transmitter/receiver electronics in two parts connected with a large bandwidth and shielded cable.

Testing was executed first with a medium-frequency (600 MHz) GPR antenna in order to evaluate the dynamic range. Then, the electronics was mounted on a high-frequency (1.5 GHz) GPR antenna whose electromagnetic characteristics are similar to the ORFEUS front antenna. This is a quite critical phase of the project as performance of the antenna must be optimized to provide a good sensitivity to targets.

Status

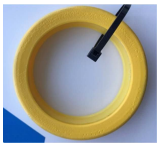
Next steps include:

- A review of design changes to the drill rod connector system and assessment of the effect upon performance
- Complete technical and contract discussions regarding communications system implementation
- Design and test drill string current and voltage measurements system
- Revise in-liner sealing in the area of connector connection and polyethylene sheathing of coaxial cable, and
- Carrying out further leak tests.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Polyethylene Systems Joint Industry Program (JIP) – A Total Quality Approach



The Polyethylene Systems JIP was established in 2016 to provide funding, guidance, and input into the process and priorities of specific R&D initiatives. One of the main goals of the program is to provide clear guidance that incorporate newly developed knowledge into currently accepted best practices.

Project Description

For natural gas distribution systems, the advantages of using modern polyethylene (PE) pipe over steel are universally accepted to the point that today PE pipe is used in the majority of all new and replacement gas pipe installations. However, the increased use of plastic materials has led to an increased level of scrutiny of PE piping systems and fusion practices. Regulators and utilities alike are looking to enhance the fusion process and implement quality controls to ensure the integrity of PE fusions and other aspects of PE pipe maintenance and repair.

In response, OTD established an industry-sponsored collaborative research program to provide funding, guidance, and input into the process and priorities of specific initiatives. The PE Systems Joint Industry Program (JIP) is focused on addressing the plastic systems R&D gaps and the standards development needed to enhance the design, installation, and operation of PE gas distribution systems.

Initial activities involve the development of a *Total Quality Approach to PE Fusion,* in which critical fusion-process parameters – inclusive of pipe, fittings, surface preparation, fusion equipment, controls and tolerances – would be clearly understood, defined, and validated for use and adoption throughout the industry.

Elements of this *Total Quality Approach* include:

- Review and definition of best practices in surface-preparation procedures
- Definition of essential variables that impact the integrity of PE fusions
- Development and qualification of new fusion procedures (as needed)
- Incorporation of the above into applicable industry standards
- Development of *in-situ* quality and process control metrics along with automated or standardized methods to ensure variables are within limits
- Implementation of appropriate tracking and traceability of PE fusions, and
- Development of field-deployable fusion non-destructive evaluation methods

The *Total Quality Approach to PE Fusion* is modeled after the American Society of Mechanical Engineers and American Petroleum Institute standards for the welding of steel pipe.

Deliverables

The deliverables for this project include:

- Establishment of a Program Advisory Team and Technical Steering Committee to prioritize and guide the efforts of this and future projects
- A well-defined set of projects and reports designed to fill in identified knowledge gaps pertaining to fusion procedures
- Clear guidance documents that incorporate the newly developed knowledge into currently accepted best practices, and
- Focused and consensus-driven efforts to improve existing standards and develop new standards where gaps exist.

Benefits

The PE Systems JIP is designed to establish a roadmap and prioritize tasks by identifying the most pressing industry needs and defining the scope of projects to address the identified needs. The JIP helps to secure and coordinate funding sources; coordinate and facilitate interaction and communication among various stakeholders; and communicate results.

"As a member of the JIP Steering Committee, I fully support the effort to improve the quality of polyethylene fusion joints. A chain is as strong as its weakest link, and a plastic pipeline is as strong as its weakest joint. Although polyethylene components are easily joined by the heat-fusion method, there continues to be an industry need to improve the overall quality of the joining method used in the field by incorporating the latest technology into our best practices."

- Dr. Gene Palermo
President
Palermo Plastics Pipe Consulting

Technical Concept & Approach

A Program Advisory Team oversees the entire program and a Technical Steering Committee was established to provide guidance to the program. The Technical Steering Committee guides the development of the research projects and scopes of work that will be performed.

Results

The PE systems JIP was established in 2016. Program members include: OTD members, associations, various other utilities, manufacturers, and contractors.

The major focus of the JIP participants is to identify and discuss industry needs, achieve consensus on prioritization of issues for project research, and participate in the direction and review of the various project efforts.

Industry discussions identified a group of needs to help enhance the overall quality of plastic piping systems. The identified needs include:

- Fusion joining preparation best practice development
- Creation of ovality and out-of-round standards, including re-rounding guidelines
- A more thorough understanding of the durability of elastomers used in mechanical fittings
- Development of design guidelines for fittings, including the interaction of multiple materials with elastomeric seals
- Understanding the impact of heavy hydrocarbon permeation in PE pipe on mechanical joints.
- Best practices for evaluating new appurtenances
- Best practices for evaluating fusion procedures, and
- Evaluation of repair methods for plastic piping systems.

In 2018, pipe-fusion preparation guidelines were developed. The effort focused on cleaning and pipe preparation – how to properly clean pipe based on different field conditions (e.g., wind, moisture, and water in a ditch); using the "one-and-done" approach by using an approved single-use towel once and discarding the used towel after each cleaning step; peeling or scraping the pipe correctly, ensuring that if any remaining contamination is present, it is fully removed; and installing and fusing the fitting promptly after scraping to minimize any future contamination.

In 2019, a series of fusion joining preparation projects were completed. Various scrapers were tested with respect to scrape depth, scrape uniformity, and contamination (bentonite powder) removal, at different temperatures. Three solvents were tested with respect to contamination removal (talc, bentonite powder, and silicone grease), with three different cleaning tools (polyester fiber wipe, paper towel, and cotton rag).

In 2020, researchers performed tensile testing on mechanical fitting joints that were permeated with a heavy hydrocarbon cocktail. The permeated mechanical joints passed the 25% pipe-elongation requirement. Analysis of the peak forces indicated that the permeated joints behaved as if they were at elevated temperature. This observation agrees with the findings in the U.S. Department of Transportation report *Effects of Hydrocarbon Permeation on Plastic Pipe Strength and Fusion Performance.*

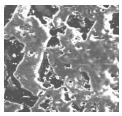
Status

The project team is currently focusing on heavy-hydrocarbon permeation projects. Projects related to hydrogen blending are expected to gain focus over the next few years.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Best Practices to Address Odor Fade in High-Rise, Low-Occupancy Buildings



Research is under way in a effort to determine the best way to address odor fade in gas pipes in high-rise, low-occupancy buildings. Researchers are developing a consistent approach for conducting odor fade risk assessments.

Project Description

Natural gas utilities are seeing an increase in new customers in urban areas in the form of high-rise buildings. These customers provide various challenges for gas utilities, including the need to address low odor readings in high-rise and low-occupancy buildings. This phenomenon – known as odor fade – is defined as the loss of odorant by physical or chemical processes occurring inside the pipeline.

In a OTD-sponsored project, it was shown that the odorant compound most impacted by fading in a steel pipe was t-butyl mercaptan (TBM). Concentrations in the gas phase were quickly lost in the presence of rust on the pipe surface.

To overcome odor fade, operators generally add extra odorant to supplement existing concentrations. In conjunction with this, natural gas flow rates can be increased to purge more gas. Unfortunately, the option of increasing flow rates cannot be used in low-occupancy buildings, where the flow is often very low to nonexistent, especially in summer months.

The objective of this project is to identify the scenarios in which odor fade may occur within complex interior jurisdictional and non-jurisdictional piping systems and determine best practices to address the phenomenon in high-rise or other low-occupancy buildings. Additionally, goals are to develop a consistent approach for conducting odor fade risk assessments within these environments, including identification of mitigation options prior to servicing a customer.

Deliverables

Deliverables from this project include:

- Survey information of the current practices to condition (pickle) steel pipe
- A laboratory assessment of selected best practices
- An odor fade mitigation guide, and
- A Final Report with summaries and recommendations.

Benefits

Loss of odorant effectiveness in natural gas is not a new phenomenon. However, it has become a high-profile issue for the natural gas industry due to recent incidents and increased litigation due to perceived odor fade.

Results from this project will help to increase the safety of natural gas delivery systems and enhance the integrity of the infrastructure.

Laboratory testing.

Technical Concept & Approach

The project has two parallel paths: one involves a survey of industry best practices and combining it with knowledge to date. The second path involves laboratory testing of a selected mitigation pathway.

Project sponsors and others will be surveyed for their typical practices in low-flow or locked-in situations. Information gleaned from odor-fade projects will be added. The American Gas Association also publishes information that will be included. This information will be summarized, chemically evaluated, and presented to project sponsors.

Selected techniques are being evaluated under laboratory conditions. The gas will initially be odorized with tetrahydothiophene and/or TBM, using house gas or synthetic odorized gas.

Results

For the tests, a series of ball valves was used to control the flow of the gas and ensure limited interaction with non-inerted surfaces. By comparing the difference in concentration between the inlet and outlet sample points, the amount of odorant loss can be quantified.

In 2019, a new task was performed for a project sponsor investigating a pipe implicated in odorant fade in an apartment building. An oily residue and pipe dope was found on the interior surface. Visual examination of the pipe interior found a white/gray colored surface contamination on the pipe interior that was oily to the touch. This material was isolated and identified as the same pipe dope used to connect the pipe to the tees. The oily residue is surmised to be from cutting fluid used to make the pipe threads. This oil appears to have softened the pipe dope and allowing it to spread out beyond the joints where it was applied, possibly in excess.

Additionally, the research team completed test execution and results reporting of all activities performed under the laboratory evaluation portion of the project scope. Sponsors indicated they have an interest in understanding the impact of rust on time to saturation for uncoated steel pipe, and calculating during project planning when odor fade may occur, which was not part of the original scope. In the interim, the team produced an initial time to saturation analysis to outline the methodology a utility could use to develop a "rule of thumb" estimate the risk of odor fade for a given scenario.

During 2021, two distinct methodologies for incorporating rust into the time to saturation analysis were identified. The project team and sponsors agreed on a hybrid of the two approaches in which pipe samples from project sponsors would be combined with samples environmentally conditioned to perform the rust characterization analysis.

Specimen samples.

Technicians modified a new testing rig. Pipe samples were secured and processed. This processing includes pictures, examination, and collection of loose surface rust. Sample pipe was cut into four-inch segments and cut axially. Rust generation, collection, and characterization was completed. Rust collected from the laboratory samples and other legacy pipe was sent for x-ray diffraction spectroscopy, surface area analysis, and scanning electron microscopy with energy dispersive x-ray spectroscopy.

Status

In 2022, researchers will complete testing at residential infrastructure pressures and flows and deliver the project Final Report.

By controlling for rust sample size, system pressure, and temperature, researchers intend to quantify odor fade at different pressures, absorption path lengths, and environmental conditions.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Material-Supplier Quality-Assurance Program

Through the development of a material-supplier quality-assurance program, efforts are being conducted to create a standardized approach to key processes affecting the quality of materials used by gas utilities.

Project Description

Natural gas utilities are required to implement integrity programs that focus on system risk assessment that includes purchased materials. However, while utilities are responsible for the quality of the materials, the manufacturers producing materials for the industry are not under the same level of scrutiny. Due to a lack of clear industry guidance, utilities often create their own sets of requirements (test conditions, traceability, packaging, etc.), with a main focus on technical characteristics and less attention on process-related activities. The diverse range of requirements from utilities diminishes product quality due to variations infused into material operation processes. This requires manufacturers to allocate additional resources to control these variations, which leads to increased cost.

The objective for this project is three-fold:

1. To assist gas utilities in creating best-practice guidelines
2. To create a standardized approach to key processes affecting the quality of materials, and
3. To identify comprehensive regulatory and technical requirements specific to products.

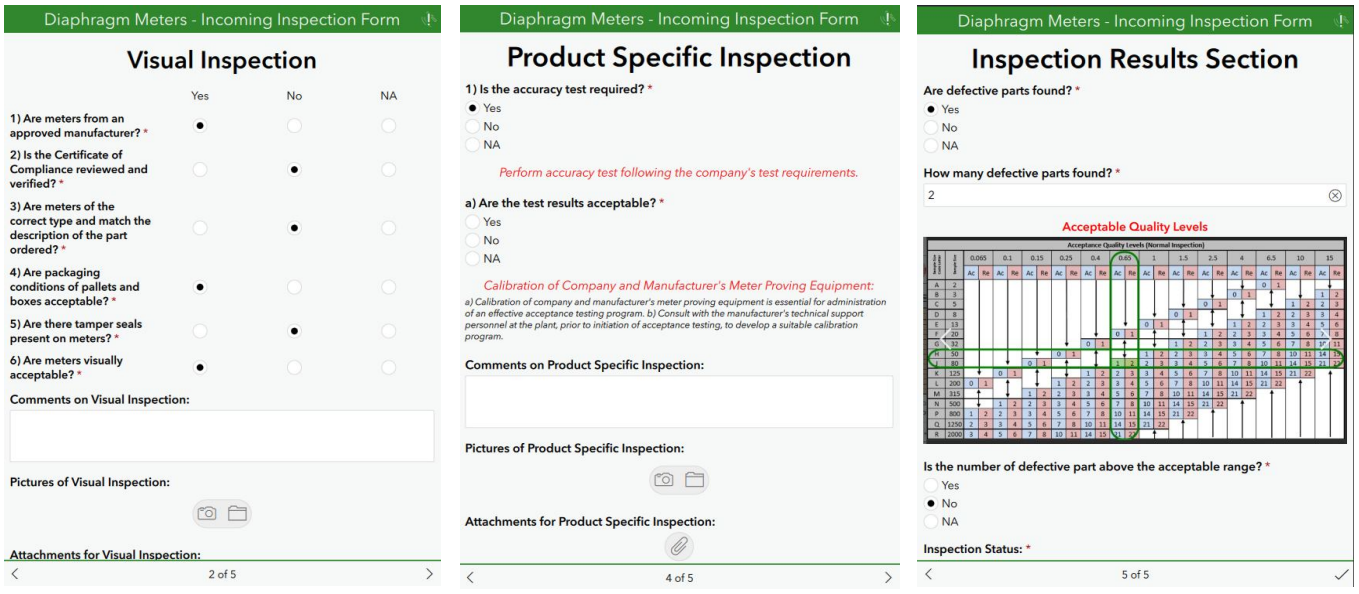
Deliverables

Deliverables from this project will include two manuals: 1) *Material Technical and Quality Requirements Manual* and 2) *Material Quality Assurance Manual*. In addition, a comprehensive set of guidelines/best practices will be provided.

Benefits

A standardized, collaborative approach to develop a material-supplier quality process will:

- Improve material quality processes by formalizing quality-assurance activities that are focused on: planning, risk assessment, and suppliers performance monitoring and evaluation
- Reduce variability by standardizing requirements
- Reduce costs associated with: materials through standardization; rejects, dig-ups, and delayed projects through material quality; and developing the program through the use of collaborative pooled resources
- Improve the understanding of applicable industry standards requirements



A wide variety of forms were developed in this project.

"PG&E was pleased to collaborate with our peer companies to create a better standard methodology we can all incorporate into our risk-management programs. We have all too often heard from our suppliers that 'we are the only one that does this,' but the teamwork on this project created a set of documents we can all leverage to make our programs stronger together."

- Jerrod Meier
Principal Engineer, Risk Register
Pacific Gas and Electric Company

- Improve communication, collaboration, and information sharing with suppliers and make more informed decisions based on data derived from supplier quality-assurance activities
- Raise the bar of overall material quality and system integrity by collaborating as a group and creating an industry standard approach to material quality-assurance processes, and
- Identify possible gaps in current standards and regulatory requirements.

Technical Concept & Approach

This is a collaborative program that includes a steering committee comprised of representatives from each participating sponsor along with subject-matter experts (SMEs). The steering committee is responsible for providing relevant information, communicating expectations as to the direction of the program, participating and providing feedback in the development of the manuals, and identifying priorities as to the project deliverables.

This program will define a manual/handbook with comprehensive material requirements and best practices of material-supplier quality-assurance processes (methods, policies, and procedures) that will help utilities to control and improve material quality and, therefore, overall system integrity.

Specific tasks include:

- Project Scoping and Gathering of Information
- Gap Analysis of Product and Process Requirements
- Gap Analysis of Utilities' Internal Material-Supplier Quality Processes
- Development of Material Technical and Quality Requirements Manual for Material Suppliers
- Development of Material Quality-Assurance Manual for Utilities.

Results

Throughout this program, the project team collected more than 190 technical specifications, conducted a gap analysis, and created comprehensive technical product specifications for 22 product families.

Researchers reviewed and created eight best-practice quality procedures for utilities' internal use, including a Purchasing Quality Manual.

Also, 25 quality forms were created to collect qualitative and quantitative data. These forms will be converted into electronic smart forms available on mobile devices to simplify digital data collection, monitoring, and analysis during Phase 2.

In 2021, a sponsor survey was developed to gather information regarding Esri GIS systems and current utilities' systems for quality data collection.

Forms created during Phase 1 included:

- Incoming Inspection Form for 18 Product Types
- Supplier Self Evaluation
- Product Qualification Requirements Checklist
- Supplier Performance Evaluation
- Internal Audit Checklist
- Control of Nonconforming Material Report
- Corrective-Preventive Actions, and
- Calibration Record.

The project team initiated the process of converting the forms to the Survey123 format, as well as developed a quality-control procedure to review the forms as they are completed.

Researchers completed design of forms and their functionalities for 100% of the forms.

Status

Researchers are completing the conversion of design forms to Survey123 forms.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Field Testing of Nano-Technology Coatings to Reduce Aboveground Corrosion

To address corrosion concerns, field trials were performed on aboveground utility assets with unique and promising coatings for challenging utility corrosion-prevention applications. These coatings have the potential to substantially reduce wet/dry aboveground corrosion in various areas of application.

Project Description

Utilities have long expressed interest in the development of improved pipeline coatings for challenging environments. Of particular concern are applications for aboveground facilities.

The concept for this project came from needs expressed by a utility group wanting to explore superhydrophobic nano-coatings to improve corrosion resistance in high-risk areas. Other utilities are interested in testing these novel coatings in snow/ice areas, as well as bridge crossings that have significant, industry-wide issues with caustic leafing corrosion from bird droppings.

For this project, field trials were performed with three relatively new, unique coating systems:

- A calcium-sulfonate-based coating
- A water-based zinc-galvanizing compound, and
- A zinc silicate waterborne coating.

The high-ratio co-polymerized calcium sulfonate proprietary formulation has the unique ability to neutralize acidity (passivating), create a hydrophobic barrier that repels water, bond ionically, and thoroughly wet the surface profile, making it suited for the reclamation and long-term protection of bridges, steel structures, cable-suspension systems, industrial infrastructures, highway overpasses, utility towers, and potentially pipelines.

Deliverables

Specific deliverables from this project include:

- A set of applicable use cases in a gas utility for these coating systems
- Completion of set of field tests
- A coating-performance summary
- Recommendations for specific uses of the product, and
- A Final Report detailing all activities.

Benefits

For aboveground assets, operators cannot rely on cathodic protection to backup coating protection; therefore, operators seek to specify and apply the most appropriate and best-performing coating system available. By providing long-lasting coating protection, operators can reduce the amount of rework needed on their aboveground systems.

Some aboveground piping locations are very difficult to access and require permitting, multiple crew members, and special equipment and vehicles to inspect and/or repair coatings. These include highway and bridge crossings, water crossings, and vaults. Operators that have outdoor meter sets and regulators also experience snow and ice damage of these assets.

Field testing these unique coatings in the natural gas utility environment will give operators data to support their use to reduce system damage and loss of integrity, thereby reducing the risk of system leaks or failures. By testing the coatings under varying climate and system configurations with different operators, researchers will obtain a more complete picture of product performance in a variety field sites.

Overview of Coatings

Single-component high-ratio, co-polymerized calcium-sulfonate alkyd coating

- Sulfonate-carbonate crystals form a path that water must pass through before it can reach the substrate
- Surface tolerant, hydrophobic and moisture displacing
- Alkaline pH (~10.5) neutralizes active corrosion cells in existing rust
- Primary commercial application is overcoating of steel bridges
- Resist cracking from thermal and hygro-thermal stresses.

Water-based, two-part zinc galvanizing compound

- Zinc/zinc oxide powder + liquid binder free of all solvents and volatile organic compounds
- The dry film is 93 wt% zinc
- Per the manufacturer's own tests, it is rated at 10,000 hours on the ASTM B117 salt spray test
- Requires a bare metal surface
- Power tool cleaning is sufficient
- Can be applied by brush, roller, airless, or conventional spray.
- Application is by conventional spray.

An inorganic zinc silicate waterborne coating system consisting of two components: potassium silicate binder and zinc powder

- Developed by NASA to protect launch facilities in the highly corrosive environment of Florida's coast
- The potassium silicate binder allows the coating to be applied across a broad range of temperature (40F°-118°F) and humidity (0-94% RH)
- Can be top-coated after two hours
- Bonds chemically to the steel substrate and is highly resistant to undercutting
- Application is by conventional spray.

Technical Concept & Approach

- Use case and field site selection *(completed)*
- Product review and selection *(completed)*
- Development of a field-testing protocol and testing matrix *(completed)*
- Field trials and performance assessment *(in progress)*.

Results

Field trials were successfully completed in 2019.

The project team completed and distributed the:

- Concise Field Applied, Aboveground Coating Best Practices
- General Surface Preparation Guidelines
- Guidance on what type of scribe tool to use and how to purchase that option
- Manufacturer recommendation for application brush type for zinc coatings, and
- Field site key lessons learned.

All of the coatings have temperature/humidity/dew-point restrictions. This will most likely be a challenge on the low-pressure side of regulators. Each field site sponsor invested a significant amount of time and expertise towards the field trials. The project now has an outstanding set of field sites that will go through four seasons of exposure and then be assessed for performance.

In 2020, field applications continued. Five sites are being used for testing. These include: 1) a desert site with hot, dry sunshine; 2) gate station regulator piping on the ocean shore containing complex shapes, salt contamination, and temperature changes; 3) a bridge crossing with caustic bird droppings, wet/dry moisture, and road salts; 4) ice-formation sites at regulator stations; and 5) a compressor station with high/low temperature swings.

The project is in the planned "field exposure" phase, with the coatings logging time at their respective application sites. This phase of the project will continue until COVID restrictions are adequately lifted to allow travel, meeting in person, and efficient inspecting of the facilities. The extra time of exposure will benefit the meaningfulness of the assessments.

Status

In approximately a year, researchers will start the assessment of the coating performance with visual inspections, photography, root-cause analysis, and quantitative testing for rust and blistering.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Leak Seal for Meter-Set Joints

Research in this project is focused on the evaluation and commercialization of a new method to seal thread leaks on meter set assemblies. The evaluation is being conducted to establish ease of use and permanency.

Project Description

Some utilities are now classifying and logging leaks on residential and commercial meter set assemblies (MSAs), and many have established that a significant number of the leaks occur at threaded joints between components. Currently, a common practice is to dismantle an MSA once a leak has been detected, reseal the leaking joint, and reassemble the MSA, which requires customer downtime, relights, and time involved in conducting the repair. However, many of the components (other than the thread area) are in good working condition and not requiring replacement.

For many years, pipe "dopes" (joint sealants) have been used as one method of ensuring proper sealing of threads. Solvents in the pipe dope provide stability during application and ensure a proper cure. When the solvent evaporates, the product dries to form a tough seal. Unfortunately, when dried, the bond can also become rigid and brittle in nature. Aging and temperature cycling can cause these rigid sealants to crack, creating small leak paths around the pipe on the unsealed threads. As the cycling continues, crack propagation continues and increases the severity of the leak.

Often, leaks are so minor that they can only be detected by application of a liquid leak detector. For these instances, the removal and resealing of the leaking component is especially time consuming and disruptive.

In this project, researchers are investigating alternate solutions involving the application of a spray-on or a brush-on material to the leaking threaded joint to permanently stop the gas leak. Researchers identified various spray-on, brush-on, putty, or epoxy solutions, and are developing a product in collaboration with a sealant resin manufacturer.

The objective of this project is to commercialize a permanent leak sealant for non-hazardous low-pressure gas leaks on MSAs.

Deliverables

The deliverables from this project include development of a fast-curing, easy-to-apply permanent leak sealant product for non-hazardous, low-pressure MSA thread leaks that has been laboratory tested and formulated specifically for the natural gas industry.

The project team is also executing a field pilot study for the product.

Benefits

Utilities could more effectively and efficiently address leaks on MSAs if an easy-to-apply system was identified and validated for use on low-pressure natural gas leaks. Addressing these very small "nuisance" leaks on

Left: Leak detection size of bubbles prior to repair; right: example of repaired leak after putty is applied.

MSAs will assist the industry in minimizing the effect of one source of methane emissions and reduce the time and cost associated with performing this maintenance operation.

Technical Concept & Approach

The initial task for this project included an in-depth review of the commercially available products that can be applied to metallic MSA components to stop leaks.

Other tasks included:

- Resin Manufacturer Collaboration and Reformulation
- Short-Term and Long-Term Leak Repair Testing
- Field Pilot Study, and
- Commercialization of Reformulated Product.

Results

In Phase 1, researchers evaluated more than 20 leak-sealant products. Through this evaluation, several putty-style leak-sealant products were identified that could potentially provide efficient and effective ways to permanently repair small non-hazardous low-pressure gas leaks.

In 2019, short-term testing of the different leak-sealant products was completed. This testing consisted of applying the sealant product to one-inch threaded pipe joints. The testing included evaluation of sealant reaction to leak soap and gray meter paint along with the overall cure time of the product. The products that successfully passed the short-term test protocol were then put through the long-term test protocol. The repaired specimens were evaluated by subjecting them to temperature cycling in an environmental chamber.

Researchers tested and evaluated three leak-repair methods for their ability to repair small-thread leaks typically found on the low-pressure side of an MSA. The procedures for installing these leak-repair systems were developed through testing and in collaboration with manufacturers. All three leak-repair methods yielded positive results during testing.

This project also involved a pilot project with gas utilities where crews tested these leak-repair systems by repairing natural gas leaks in the field.

The project team corresponded with a manufacturer about optimizing the installation procedure for its leak-repair kit that is currently being evaluated by the project team for its ability to repair low-pressure leaks at threaded meter-set connections. In addition, alternative leak-sealing methods and commercially available materials were evaluated.

"Currently, meter-set emissions account for 20% of PG&E's overall emissions. The leak seal for meter-set joints project has the potential to repair these meter-set leaks sooner, thus reducing our overall emissions. In addition, there is the added safety benefit by reducing the amount of strain and physical work to break down meter sets to repair these leaks."

- Stephen Ramos
Gas Operations R&D and Innovation
Pacific Gas and Electric Company

The research team added another commercially available product and vendor to the evaluation. One product uses a similar putty to initially seal the leak and then a two-part epoxy to reinforce and cover the leak area. Another method being evaluated is the application of butyl tape (in advance of the application of an epoxy putty) and then sealing the area with a self-fusing silicone wrap. Utilities will field test these methods and provide feedback on their effectiveness and utility.

The goal is to install 20 repairs for each leak-repair solution and monitor over a 90-day period. These results will then be shared in the Final Report.

The project team created installation instructional documents for three leak-repair products and also made instructional videos that demonstrate the leak-repair procedure of each product.

As requested by project sponsors, tests were conducted using higher-pressure leaks (~0.04 scfh at 60 psig). The leak repair methods were found to not be very effective at repairing these types of leaks and researchers cannot recommend using them to repair higher-pressure leaks in the field in their current form.

Status

The project team is finishing testing of leak-repair products. Team representatives continue to support and monitor ongoing pilot programs.

A Phase 2 Final Report was issued in October 2021.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Advanced Metering Infrastructure Communications Protocols

In this project, researchers investigated developments in advanced metering infrastructure communications platforms. This study will help utilities identify vendor solutions that are truly interoperable and offer standard interfaces between disparate utility systems.

Project Description

Many gas utilities are migrating from automatic meter-reading (AMR) systems to advanced metering infrastructure (AMI) platforms due to AMI's ability to support devices that offer increased operations and environmental monitoring.

While some manufacturers claim that their systems support "open and interoperable" communications with field devices, closer inspection reveals that sometimes these communications occur over proprietary networks.

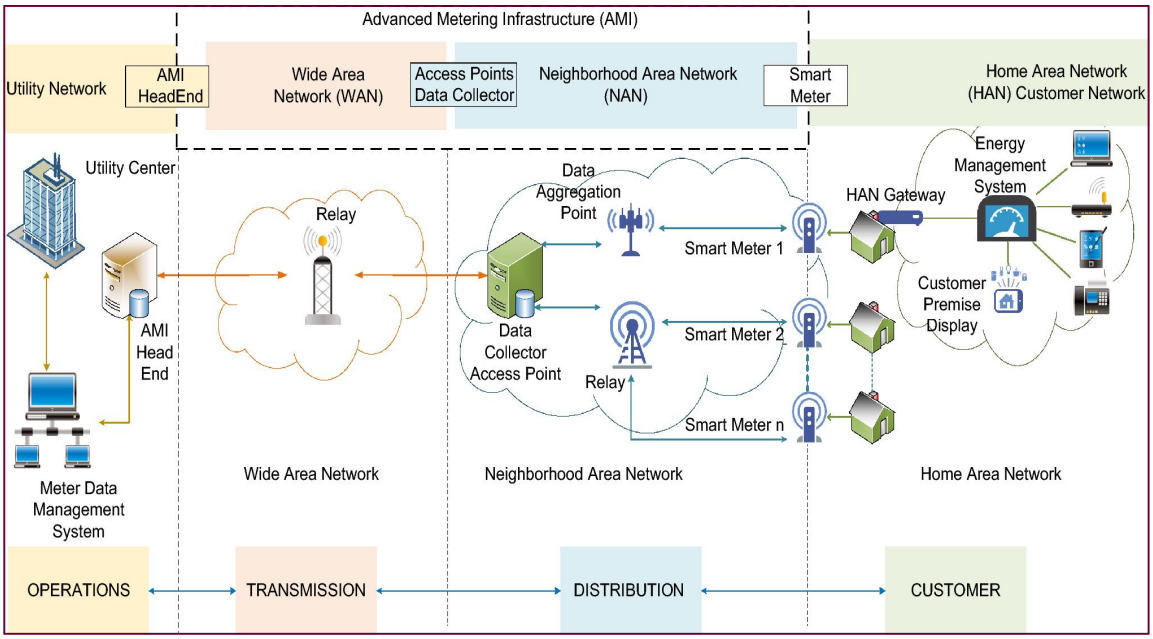
Research in this project was conducted to help identify the characteristics of truly open communications protocols so gas system operators may make informed decisions when choosing an AMI system provider. The focus was on recent developments in AMI communications platforms. The intent is for utility operators to use the study's findings to identify vendor solutions that are truly interoperable and offer standard interfaces between disparate utility systems.

Open communication protocols are important because they allow operators to implement the various smart sensors and other devices (e.g., shutoff valves, methane sensors, etc.) that are now being developed and commercialized. Several major AMR/AMI vendors endorsed open communication protocols and an industry group, Wi-SUN (Wireless Smart Ubiquitous Network) Alliance, was formed to curate these standards.

Deliverables

The results of this research are presented in a Final Report on the state of the art of the AMI communications protocol industry. This report provides:

- A review of the mission, goals, charter, and scope of the Wi-SUN Alliance
- Information on participation in the Wi-SUN Alliance
- The methodology and challenges associated with validating that a device conforms to the Alliance standard
- A summary of what is on the horizon for AMI devices, and
- An outline of next steps for follow-on project phases.



Benefits

The primary benefit of using systems that operate on open AMI standards is the ability to realize additional value from the infrastructure beyond customer meter reading. For example, companies that have invested in AMI would also gain the ability to add sensors and actuators to that infrastructure, including distributed methane sensors and gas shutoff valves. An open AMI connection standard will also accelerate innovation of goods and services. The challenge in the current AMI environment is being able to ascertain which vendor solutions are truly interoperable and which make interoperability claims but rely on proprietary network communications. This project will help overcome this hurdle by providing a methodology to sort through a vendor's claims and identify truly open AMI solutions.

Technical Concept & Approach

In this project, researchers investigated the Wi-SUN Alliance to determine if any of the current Wi-SUN-certified devices are of value to gas distribution companies.

Specific activities include:

- **Wi-SUN Alliance Engagement**

  Researchers engaged Wi-SUN and determined how well its activities and standards align with gas industry needs.

- **Apply Wi-SUN Standards to AMI Open Standard Devices**

  The project team analyzed the open and interoperable standard(s) endorsed by the Wi-SUN Alliance.

- **Define AMI Open Standard Device Use Cases**

  In this task, the project team identified the AMI application devices that are of greatest interest to the project sponsors.

Results

The project team gained familiarity with the Wi-SUN Alliance organization through a review of website documentation, videos, and supporting materials A Contributor membership to the Wi-SUN Alliance was approved, which allows participation in and voting privileges for working groups and committees, among many other benefits.

The project team purchased hardware sensor devices and successfully executed a demonstration program in support of the standard endorsed by the Wi-SUN Alliance.

In 2018, the Wi-SUN Alliance launched a Field Area Network (FAN) certification program. The FAN certification process is intended to address two goals: 1) to verify that FAN devices from different manufacturers are interoperable and 2) to verify that certified devices provide a reasonable level of security for that device's purpose. This framework is intended to create an ecosystem of devices that can readily interoperate.

The Wi-SUN Alliance is promoting open standards for communication based on the IEEE 802.15.4g wireless standard. On top of this communication, Wi-SUN is also promoting IPv6 addressing and security protocols based on best practices.

The project team identified various equipment, such as wireless sensors, that adhere to the communication standard. The purpose of this activity is to investigate the feasibility of adapting these existing components to the Wi-SUN framework.

The research team identified that the use case of highest interest to the gas industry at this time (excluding metering) is the monitoring of methane. This is being driven both by safety considerations and by increased scrutiny of greenhouse gas emissions. There is also interest in the use cases of cathodic-protection monitoring and pressure monitoring.

Several approved testing laboratories for Wi-SUN compliance are now operating. The first five products completed and passed Wi-SUN certification during 2019.

Project activities in 2020 included investigating additional hardware that may be useful to gas utilities.

Key developments include the establishment of mesh networks as a viable communications platform for achieving desired use cases. The Wi-SUN Alliance's intent to certify battery-operated devices in its second version of its field area network specification is critical to gas implementations. Mesh implementations have demonstrated that a mixture of battery- and line-powered devices produce a viable solution.

Status

This project is complete. A Final Report was issued in May 2021.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Uniform Frequency Code

The goal for this project was to create an industry standard, guideline, or best practice for underground utility markers used to locate buried facilities. This best practice would ensure consistency among stakeholders' future identification of underground assets.

Project Description

In the past, as utilities buried their infrastructure, many locators relied on hand drawings or computer models based on estimated distances of buried pipe or cable. This created a challenge in identifying where to excavate for construction and repairs without running the risk damaging the buried utility.

In response, underground frequency markers have become a tool used in marking and identifying buried utilities. Underground frequency markers provide a low-cost, efficient option of placing the marker with the buried utility and locating the marker through use of locators tuned to the marker's specific frequency.

Underground frequency markers are devices that generate an electromagnetic radio wave frequency to signal the location of an underground facility. Underground utility markers can locate and identify an underground utility in two ways:

1. The electronic marker radio wave can carry identifying data from the chipset in the marker associated with the underground utility, or
2. The underground utility marker can transmit a radio wave frequency that is a match to a predefined utility type.

As these markers became more popular in the industry, different arrays of tools utilizing this technology were developed. However, as many utility sectors such as water, gas, and electric encompass the same buried areas, it became beneficial to assign a frequency signal to each respective utility. To distinguish between separate utilities, a range of frequencies was developed for each utility and a color applied to each marker. However, there is no official standard of frequencies used for markers with separate utility designations.

The objective for this project was to create an industry standard, guideline, or best-practice uniform frequency code for underground frequency tags/markers used to locate buried utilities. This code would establish a consistent frequency setting for markers based on their respective utility designation (gas, electric, water, etc.).

PE pipe with locatable tags attached.

Deliverables

- An assessment of the currently used, but unofficial, frequency range as a proposed standard uniform frequency code for locating buried utilities
- A proposal document to have the underground utility markers language adopted into a best-practices or standards format within the industry, and
- Obtaining a published underground utility markers new best practice.

Benefits

Formalizing uniform frequency ranges for underground utility markers would make the product evaluation and use of the product a more efficient process, as all locating equipment would search for the single frequency related to each specific utility. Also, as a range of frequencies has already served as unofficial identifiers of each utility, it would be beneficial to make this the standard range to continue consistency and form a base for future products introduced. In theory, such a code would establish a consistent frequency setting for markers based on their respective utility designation such as gas, electric, and water, among others. A standard range of frequencies would be beneficial to promote consistency, ensure the long-term use of marker technologies, and form a base for the interoperability of future products introduced.

Technical Concept & Approach

The research team examined the most frequently used frequency range in the industry and verified the frequencies used by tag manufacturers. This also includes assessing this range's use in locating products across the industry. The team produced a guideline document in order to share the information gained from this project and achieve industry acceptance.

Results

For this project, a uniform frequency code was drafted and consensus language finalized to produce two best practices and supporting documentation for publication in the Common Ground Alliance's (CGA) Best Practices Guide, Version 18.

A Working Group Task Team was formed early in the project to advance the creation of the uniform frequency code best practice while adequately addressing two concerns regarding how a standard range of frequencies might potentially limit future growth in related technologies and might require reliance on potentially proprietary frequencies. The resulting effort of the Working Group Task Team was a comprehensive proposed best practice that included a Practice Description that described installation, location, and data-integration factors to consider related to electronic markers.

Underground frequency markers.

The CGA Best Practice Committee agreed to form a Transaction Record (TR) Task Team to finalize the language drafted by the Working Group Task Team into best practices for publication in the Best Practices Guide. Initial work by the TR Task Team focused on dismantling the Working Group text into multiple best practices and supporting documentation, as there was wide agreement the original text was too broad in its scope and too lengthy in application.

In 2021, the project team participated in the CGA's Best Practice Committee meeting in June.

Best practices were established for Underground Electronic Utility Markers and As-Built Mapping of Underground Electronic Utility Markers. Early on in the project, concerns were raised about establishing a best practice that prescribes marker frequency ranges and its impact on future marker-related technology development and reliance on proprietary frequency ranges. While achieving agreement on specifying frequency ranges within a best practice was not possible, it is a significant accomplishment of this project that a table of commonly-used frequencies for various underground electronic utility markers is now and always will be included in Appendix B – Uniform Color Code and Marking Guide of CGA's Best Practice Guide.

Status

This project is complete. A Final Report was issued in February 2022.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Performance, Durability, and Service Life of Residential Gas Regulators

The objective of this project is to determine the durability and expected service life of common residential natural gas service regulators. Utilities can include service-life predictions as a basis for their residential regulator replacement plan.

Project Description

As with other components in the gas-delivery infrastructure, regulators are expected to be replaced in accordance with their service-lifetime predictions. Many parameters affect the life performance of regulators and manufacturers do not commonly provide the expected lifetime of their products. Utilities accordingly rely on short-term data, repair history, and experience with certain types of regulators to set the number of years for regulator replacements.

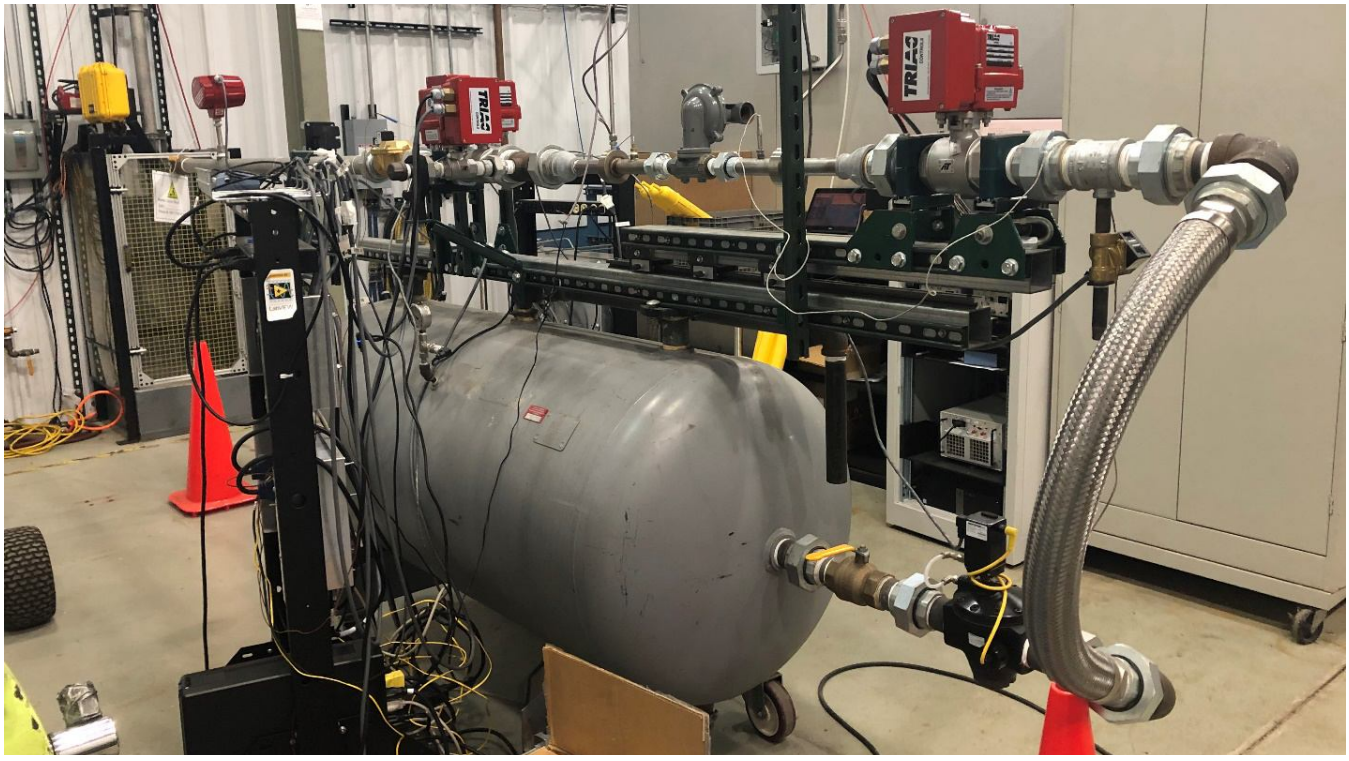
Traditional internal relief valve (IRV) regulators have a cast-iron body and a die-cast aluminum case that houses the diaphragm. These materials are usually coated in order to prevent corrosion. Moisture intrusion into the main body cavity of the regulator can corrode the regulator's inner components, hinder its ability to accurately regulate gas pressure, and could potentially cause a leak. The inner components of the regulator (e.g., the springs and elastometric diaphragms) also may slowly wear during temperature changes and normal operations over time and contaminate the gas stream. The long-term performance of regulators would vary for different manufacturers, regulator models, age, and various service and environmental conditions.

The objective of this project is to determine the durability and expected service life of common residential natural gas service regulators. Utilities can include service-life predictions as a basis for their residential regulator replacement plan.

Deliverables

The following deliverables are anticipated from this project:

1. Identification and information gathering of regulator models regarding their long-term performance and durability
2. Analysis findings of in-service regulators, and
3. A Final Report.



Regulator flow testing rig.

Benefits

This project is expected to provide savings to utilities and avoid costs associated with labor, material, and unnecessary customer service interruption. Utilities will be provided with results and technical support for a better understanding of the expected service life of regulators to optimize replacement programs.

Technical Concept & Approach

In this project, a comprehensive study of failure modes of regulators was conducted. In addition, a study of previous research and testing requirements on regulator performance was performed.

Researchers tested a statistically significant set of residential regulators which were in use for a various number of years (failed and non-failed regulators). The set represents various ages, manufacturers, types, service environments, and service conditions. These regulators were subjected to failure analysis to identify their failure modes and/or state of performance.

The testing protocol involved long-term cycling flow/lock-up and pressure relief capacity tests at various percentages of the outlet set pressure and at various environmental and gas quality conditions.

A test rig was configured that allows testing at various temperatures and other environmental conditions. The design of the system allows for applying an air-pressurized system for mechanical failure in selected environmental-controlled tests.

Results

During this project, the research team identified the causes of service regulator failures through surveys and interaction with gas utility managers. The leading causes of service regulator failures are:

- Debris/contaminant build-up, typically at the orifice
- Diaphragm rupture (typically seen in old regulators) triggered by flow surge/over pressurization,
- Material deterioration due to exposure to severe environmental conditions such as high humidity, and
- Pressure fluctuations during service lifetime.

However, due to the limited availability of service regulator failure records, it was challenging to determine a ranking of failure causes, although, anecdotally, many operators mention debris/contaminant build-up at the orifice as the more common cause of regulator failure. In light of these findings, it is evident that the service lifetime of regulators depends not only on the build quality of the regulator, but also on the external factors such as quality of gas and presence of debris and contaminants. The long-term endurane of service regulators was tested. One of the regulator manufacturers had tested service regulators by subjecting them to more than a million endurance test cycles, well above the 100,000 cycles stipulated by ANSI B109.4 standard, and they did not observe regulator failures. Based on the empirical evidence of the low failure rate of service regulators and the performance of service regulators subjected to endurance tests and other laboratory evaluations, it can be implied qualitatively that the reliability and durability of service regulators are high.

In 2021, the project team completed a software upgrade and endurance testing of the service regulator. The flow rig control software was upgraded to include looping capability that enables pressure cycling.

Status

The project team contends that it may be more prudent to focus research on regulator design improvements to reduce the impact of gas contaminants (which appears to be one of the main external causes of service regulator failures) rather than to invest in establishing the failure envelopes of service regulators.

The project team and manufacturers discussed various modes/causes of failure (e.g., environmental conditions, high humidity, debris/contaminants in the gas stream, and diaphragm rupture as a result of sudden flow surges/over pressurization that may have been caused by operator error). The common contaminants can be plastic shavings, weld filings, traces of heavy hydrocarbons, etc.

A Phase 1 Final Report was issued in January 2022.

A reliability assessment framework is proposed to evaluate the service regulator reliability, involving a combination of probabilistic assessment and comparison with a service regulator reliability dataset. The task to generate this dataset will involve testing multiple regulators which are sampled from different conditions such as climatic regions, manufacturer/model, regulator service age, etc. Based on prior reliability research work performed, at least 22 samples are required for each of the conditions mentioned above.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Abandoned-Line Detector

Research was conducted in an effort to create a nondestructive tool that when placed on the exterior of an exposed pipe would determine if the pipe is abandoned or in use. Designed for use on both metal and plastic pipes, multiple on-board sensors would identify if natural gas or live electrical lines are present within the pipe.

Project Description

Currently, the industry lacks a quick, external method for determining whether an unidentified pipe is abandoned or in use. For this project, a proven technology was integrated into a new tool to create a nondestructive tool that when placed on the exterior of an exposed pipe will determine if the pipe is abandoned or in use.

Related research in this area includes the completed OTD project 5.8.d *Tool for the External Classification of Pipe Contents - Field Demonstration,* which resulted in a tool to detect whether live electrical lines are present within a steel pipe.

Researchers expect that, with the aid of multiple on-board sensors, the tool will be able to identify if natural gas or live electrical lines are present within both metal and plastic pipes.

Deliverables

The primary deliverable resulting from project execution was a prototype system containing both hardware and software components to be utilized for non-destructively detecting whether an unidentified pipe contains flowing or pressurized gas.

Benefits

An abandoned-line detection tool has the potential to improve utility worker efficiency and safety by providing the ability to quickly and nondestructively determine whether a pipe is abandoned or in use.

Technical Concept & Approach

As natural gas flows through a pipe, it interacts with the interior pipe wall, producing subtle vibrations on the wall of the pipe that can be detected using sensitive equipment. In a very similar way to how the pipe-contents detector operates, these flow vibrations can be used to classify what is inside the pipe.

When natural gas within a pipe is pressurized but stagnant, it becomes difficult to distinguish as there are no vibrations to record as with gas flow or live electrical line conditions. As a result, new principles of detection, possibly based on the thermal conductivity or density of the fluid, are needed.

To address these requirements, the project scope included:

- Investigation of flowing, pressurized pipe methods
- Investigation of zero-flow, pressurized pipe methods
- Integration and design of a sensing system, and
- Construction of a system package.

Field measurements on two-inch-diameter plastic main.

Results

For this project, researchers successfully developed the supporting technology for creating a nondestructive tool, that when placed on the exterior of an exposed pipe, will determine if the pipe is abandoned or in use.

With the help of multiple on-board sensors, the tool is able to identify if natural gas is present within the pipe. The tool can be used on on both metal and plastic pipes.

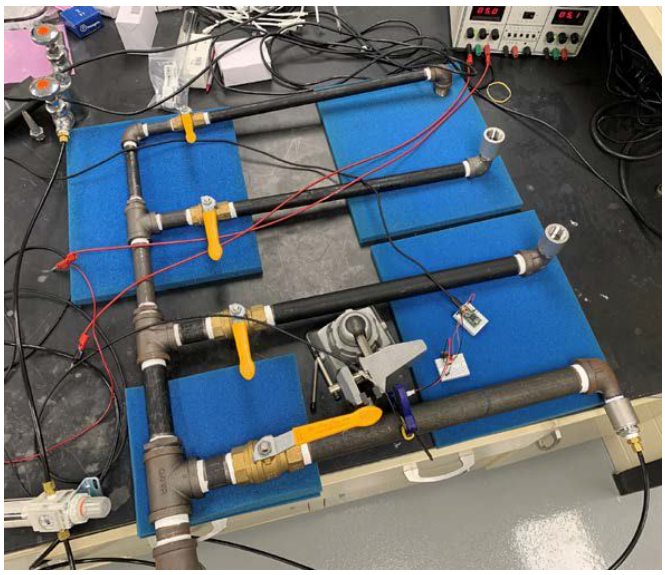
A combination of hardware and software processes were developed and tested that would allow a tool to nondestructively detect whether an unidentified pipe contains flowing or pressurized gas. The processes were based on acoustic-detection methodology and included the application of machine-learning techniques to classify broad-spectrum signals in real time, on-device.

Hardware components included a contact microphone, preamplifier, and microcontroller. The contact microphone rests on the surface of an exposed pipe, suppressing external environment noises, while gathering critical acoustic/vibrational data emanating from the pipe. A preamplifier is used to filter out unwanted signals and amplify the desired signals into a compatible range for the microcontroller to sample. The microcontroller acquires the contact-microphone signals from the preamplifier, processes them in real time, and interprets the signals based on a range of possible values. Real-time classification of the signals is enabled by the use of machine learning running directly on the microcontroller, eliminating the need to send the data off-device for processing.

Machine learning for this project was developed using large amounts of training data along with a well-defined workflow to rapidly validate models once deployed to the microcontroller. The acoustic-based detection system was tested under both laboratory and field conditions at multiple flow rates, pipe lengths, and pipe diameters.

Project results demonstrated that a tool may be developed to detect the sound of flowing gas within a pipe. The absolute thresholds for detection remain unclear, as it depends greatly on the pressure of the gas within the pipe, the flow rate, and the presence of turbulent activity. High-flow pipes or those containing turbulent activity were able to be detected with the hardware system used in this project. However, the contact microphone procured for this project did not contain the required sensitivity to detect extremely low-flow noises, for instance lines feeding pilot lights.

Technicians constructed a controlled environment to produce various levels of flowing gas through steel pipe. Sensor readings were acquired using the contact microphone, preamplifier, and microcontroller on pipe in flowing gas and zero-flow states.



Laboratory setup simulating gas flow with compressed air.

In 2020, researchers collected signal data from laboratory and field environments. Subsequently, a prototype system was developed. The prototype system was demonstrated on a laboratory setup simulating gas flow with compressed air at 0, 10, and 20 standard cubic feet per hour at 60 psi. The steel pipe under test was two feet in length with a diameter of 1.25 inches, containing bend and reducer fittings. The sensing method was a nondestructive contact microphone measuring subtle vibrations on the pipe.

Status

This project is complete. A Final Report was issued in May 2021.

The project team has identified multiple focus areas for continuing research on developing an abandoned-line detection system explored in this project. Acoustic-based detection methods for both flow-noise and zero-flow pipes should be investigated in greater detail to more clearly understand the capability thresholds of the hardware and on-device machine-learning foundations developed in this project. Conducting additional research will also afford the opportunity to potentially integrate more sophisticated functionality.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Noncamera-Based Technology to Detect Cross Bores

Research is being conducted in an effort to develop a tool to detect legacy cross bores. The initial objective is to identify viable technologies and evaluate prototypes.

Project Description

Addressing the inadvertent crossing of utility line, such as a gas pipe installed through a sewer line (commonly known as a "cross bore") remains a top priority for the utility industry in general and gas utilities in particular.

A variety of research is under way to develop cost-effective methods to identify/inspect for cross bores after trenchless installation activities. In addition, efforts are being conducted to develop technologies to identify legacy cross bores currently in the system.

In the 2010, OTD conducted a workshop to develop an R&D roadmap for addressing cross bores. The result of the workshop was a matrix of industry needs, which included tools to prevent and detect cross bores, risk analysis, best practices, information, and processes. Subsequently, OTD funded projects to identify various cross-bore technologies for detecting potential trans-sections primarily during directional drilling; develop a tool to detect hits to sewer laterals during the horizontal directional installation of gas pipes; and identified camera/imaging tools that can detect cross bores during gas pipe installations.

The objective of this project is to develop a tool to detect legacy cross bores. To achieve this, research is focused on identifying viable technologies and evaluating prototypes that can lead to the development of reliable and cost-effective cross-bore-detection tool for legacy trans-sections.

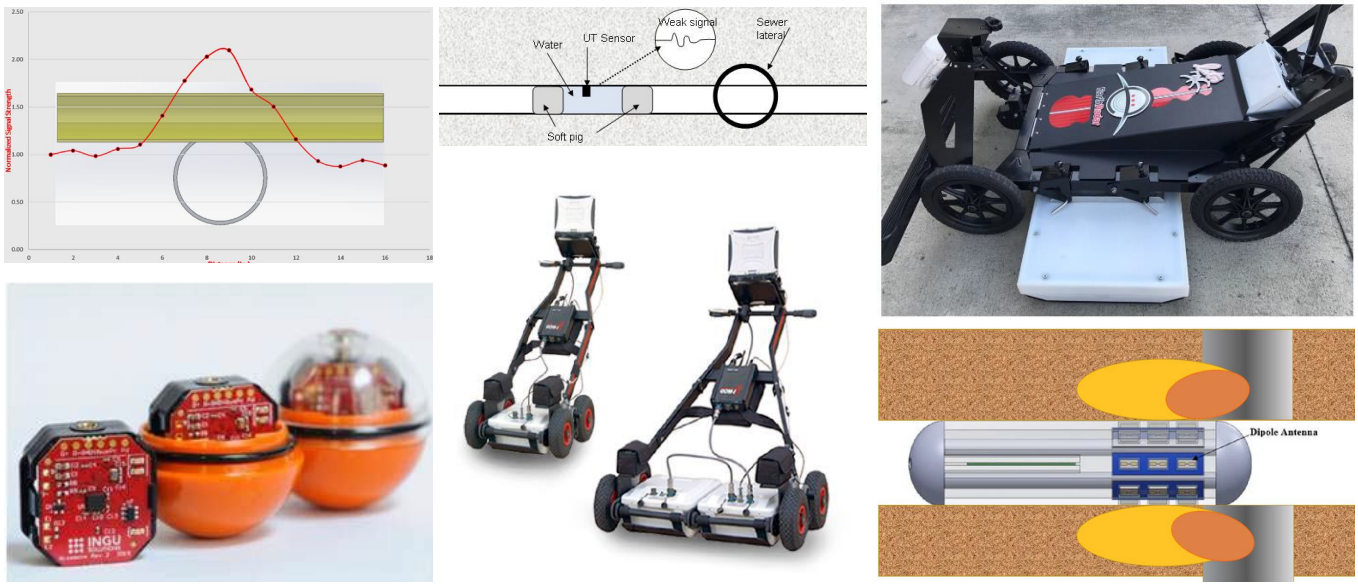
Deliverable

The deliverable for this project will be a summary report with the following content:

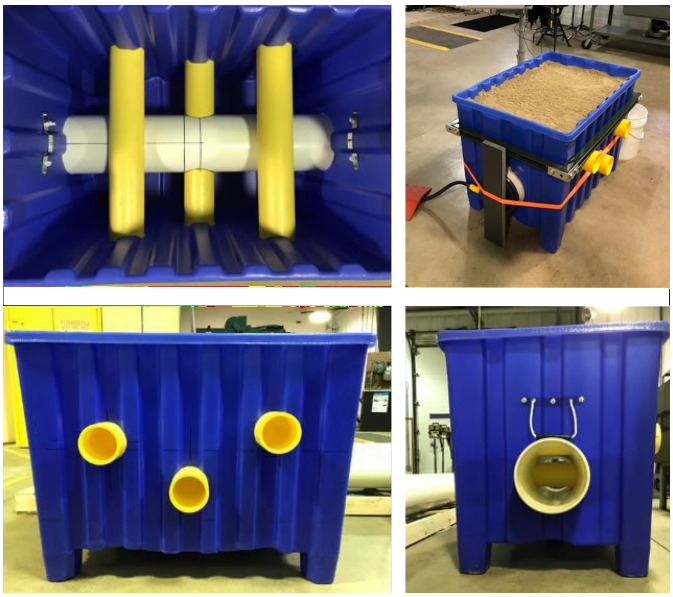
- An updated list of technologies for cross-bore detection
- Results of an evaluation of micro-impulse radar technology, and
- Prototype development details (if applicable).

Benefits

Cross bores pose a significant threat to the safety of the general public and utility workers. A reliable and cost-effective solution to this issue will help utilities to detect and eliminate cross bores and greatly reduce the associated risks and operating costs.



Researchers evaluated a variety of technologies to detect cross bores, including ground-penetrating radar, ultrasonic sensors, and acoustic-based technologies



A soil box experiment setup.

Technical Concept & Approach

Technologies used for cross-bore detection during pipe installation were reviewed and their feasibility for legacy cross-bore detection will be studied. Primary concentration was on noncamera-based technologies. In addition, suitable technologies from other industries, (e.g., mining, defense, and water) were reviewed and a feasibility analysis of adopting such a technology will be made.

Based on the results from the technology search and evaluation, researchers will proceed toward the development of a prototype system to detect legacy cross bores. Prototype development will include fabrication/ assembly of the prototype, development of an insertion technique (if needed), and laboratory-scale testing.

Activities such as prototype generation, field evaluations, and commercialization can conducted in subsequent phases.

Results

During the course of the project, the research team reviewed several technologies to detect legacy cross bores, reached out to the technology/product developers, and conducted testing to prove the concept on some of them. The technologies included ground-penetrating radar (GPR), electromagnetic (micro-radar) sensing, capacitive sensing, and vibration-acoustics sensing, among others.

A soil box experiment setup to evaluate cross-bore technologies was designed and built and the project team developed a test matrix to evaluate near-field sensing technology.

In 2019, the project team focused on proving earlier identified concepts. Technologies such as near-field electro-magnetic sensing and capacitive sensing were able to detect cross-bore (pipe intersection) that was set up for testing purposes. GPR technology and acoustic-sensing technology were also reviewed.

Researchers completed the evaluation of the electro-magnetic wave sensor. The sensor was able to detect "void" around the pipe in the laboratory-scale setup.

In Phase 1, GPRs, along with an acoustic pipe locator (APL), were selected to assess their capabilities in locating pipes and laterals on sites in San Francisco. In Phase 2, these systems were evaluated at 12 sites.

In 2020. the research team conducted a project webinar to review the interim report and obtained feedback from project sponsors. It was agreed to pursue demonstration and evaluation of commercial devices such as AM wave gradiometer (AMG) technology. A sponsoring utility agreed to identify locations and host the AMG technology demonstration.

Status

The project team is working with one of the project sponsors to identify potential cross-bore locations to conduct a demonstration of gradiometer technology. The demonstration is anticipated to be conducted by the spring of 2021 subject to prevailing local restrictions and access to demonstration sites.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Clothing Performance Guidelines to Reduce Heat Stress for Natural Gas Workers

For this project, research was conducted with the objective of establishing guidelines for selecting workwear ensembles that will provide reduced heat strain and worker comfort in natural-gas operations conducted in hot conditions.

Project Description

Thermal comfort and heat stress are significant concerns for outdoor workers in the natural gas industry. There are currently no industry-wide requirements or standards to guide the selection of fire-resistant clothing worn by workers in oil and gas operations to reduce heat strain. Few technical studies have qualified deployment of additional layers of fire-resistant personal protection equipment (PPE), such as flash-fire suits or the time that workers can operate without incurring heat stress in hot working conditions.

In this project, researchers demonstrated how modern methods of clothing comfort testing can be used to select more thermally comfortable fire-resistant clothing for natural gas workers. The objective is to establish guidelines for selecting workwear ensembles that will provide reduced heat strain and worker comfort in operations conducted in hot conditions.

Deliverables

A Final Report contains recommendations that can be used to select PPE that will reduce heat strain on gas workers in hot environments. It also provides technical performance guidelines for selecting optimum clothing configurations for climatic temperatures and solar load focused on the hot weather climates.

The project team developed scientifically qualified correlations between selected protective clothing and heat stress, and the impact of environmental and working conditions on clothing related heat strain. Researchers showed how additional PPE layers (flash-fire suits) impact worker heat stain and work tolerance.

Benefits

The outcomes of this project should be fundamentally useful to industry programs seeking to select PPE to reduce heat strain on natural gas workers in hot environments. They show how standard laboratory tests can be effectively used to assist the systematic selection or design of service uniforms and flash suits ensembles for improved thermal comfort performance. They also show how these test methods could be used to screen comfort performance claims for clothing materials and flash suit designs, and to qualify the benefits and limitations of specific PPE choices for natural gas workers.

Technical Concept & Approach

This project will quantify the role of key physiological human response variables occurring during wear of flame-resistant clothing by workers in the oil and gas industry. It will establish the relationships between the measured breathability of protective clothing materials and their comfort and heat stress using laboratory tests made on fabric swatches and protective clothing ensembles. Resultant data will be used to identify the most thermally comfortable clothing ensembles consistent with fire protection. The outcomes of this project will be used to develop work/rest cycles based on the work rate levels and temperatures encountered in wearing flash fire suits.

Sweating manikin in flash suit in a walking simulator.

This project used advanced sweating hot plates and sweating manikins to establish the relationship between the breathability of protective clothing materials and the ability of worker PPE to dissipate trapped body heat. The correlation between PPE and worker comfort and heat stress was validated in controlled wear trials.

The project team leveraged the world-class facilities of the Textile Protection and Comfort Center, the nation's leading laboratory devoted to measurement of fire-protection and clothing comfort.

Results

In this project, researchers used modern methods of clothing comfort testing to identify factors that affect the thermal comfort and heat strain of fire-resistant clothing for natural gas workers. It showed how these measurements could help guide PPE options for use in hot service areas. It demonstrated how more technically informed decisions about PPE and work conditions could reduce the heat strain of natural gas workers operating in hot environments, particularly while wearing flash-fire suits.

In 2019, a literature review was conducted to better understand how we can assist the natural gas companies with making work rest cycles based on their PPE and the environment. Results from fabric swatch tests indicates a large heat loss difference between the single-layered system and the three-layered system. However, this test was shown to overestimate the actual heat loss of a suit garment because it does not account for undergarments, air layers, added accessories, and fit of an actual suit.

In addition to these tests, technicians also measured the reflectance of the same three suit materials to the visible light spectrum. By measuring reflectance, an indication of how different fabrics might absorb heat from the sun is determined.

Laboratory tests showed that the small differences in the thermal insulation and breathability of shirt/pant service uniforms are unlikely to translate to significant difference in worker heat strain when worn without a flash suit. Sweating manikin tests of both flame-resistant (FR) and non-FR shirt and pants work uniform revealed little difference in body heat loss. Observed differences in material and heat transfer properties are more likely to affect subjectively perceived comfort related to fabric softness, visual aesthetics, or even bias against FR clothing materials for service uniforms.

The project team used a physiological model to estimate clothing adjustment factors (CAFs) for a variety of different flash suits worn by natural gas workers. As expected, when worn over work uniforms, three-layer flash suits rate higher clothing adjustment factors compared with single-layer and double-layer garments, indicating their higher contribution to the risk of heat stress. Three layer flash suits add 10-13°F when worn over a service uniform. Single layer falsh suits add 3-7° F, if worn over a service uniform. A two-layer flash suit/service uniform system adds 7-8°F to the heat index. CAF factors also show the significant effect of wearing a service uniform under a flash suit. Single-layer flash suits have CAFs in the 0.9 to 1.8°F range when worn without a work uniform underneath. These findings indicate that wearing a lightweight flash suit without a work uniform underneath could lower the risk of clothing-related heat stress.

Researchers estimated the effects of gas worker service uniforms and flash suits on idealized work/rest tables in emergency and non-emergency conditions. The analysis showed that the choice of uniforms and flash suits can have a significant effect on the work/rest cycle. Intensive work in hot conditions wearing thick clothing predictably results in much less work time and a need for longer rest periods. In addition, wearing a FR service uniform shifts the heat index toward shorter work cycles in comparison to wearing a non-FR uniform under the same flash suit. These findings confirm that extreme environmental conditions can severely limit work tolerance time, regardless of the suit or PPE worn by the worker.

This project also identified a need for a combined heat-strain and fire-protection clothing data base. Such a data base would for the first time provide holistic guidelines for balancing fire-protective performance and comfort when selecting flash suits for natural gas workers. In addition, it identified a critical gap in the current industry understanding of the effects of FR materials and flash-suit ensembles on the fire protection in realistic flash-fire escape scenarios that involve movement and possible catastrophic break-open of fire-degraded flash suits.

Status

This project is complete. A Final Report was issued in October 2021. Researchers proposed follow-on research that would study PPE fire-protective performance in dynamic full-scale flame exposures. This research would address the need to provide a more complete picture of the performance of PPE designed to protect natural gas workers from flash fires.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Virtual Reality Training

Efforts are under way to introduce virtual reality (VR) as a training tool in the gas utility industry. This project will include a demonstration on the value that VR training can bring to the natural gas industry.

Project Description

In this project, immersive virtual reality (VR) is being investigated as a means to enhance training for the natural gas industry. VR training is a tool to deliver impactful training consistently, on-demand, and cost effectively in a wide variety of industries, including healthcare, automotive, education, military, and law enforcement.

The goal of Phase 1 was to develop a content library for utilities to assist with the training of their personnel on operations and maintenance (O&M) procedures, including emergency-response activities. These modules include randomization of training scenarios and reporting capabilities on a user's performance and areas for improvement. The modules allow for future customization with company-specific O&M procedures to test for critical-thinking skills and knowledge to fit each user's needs.

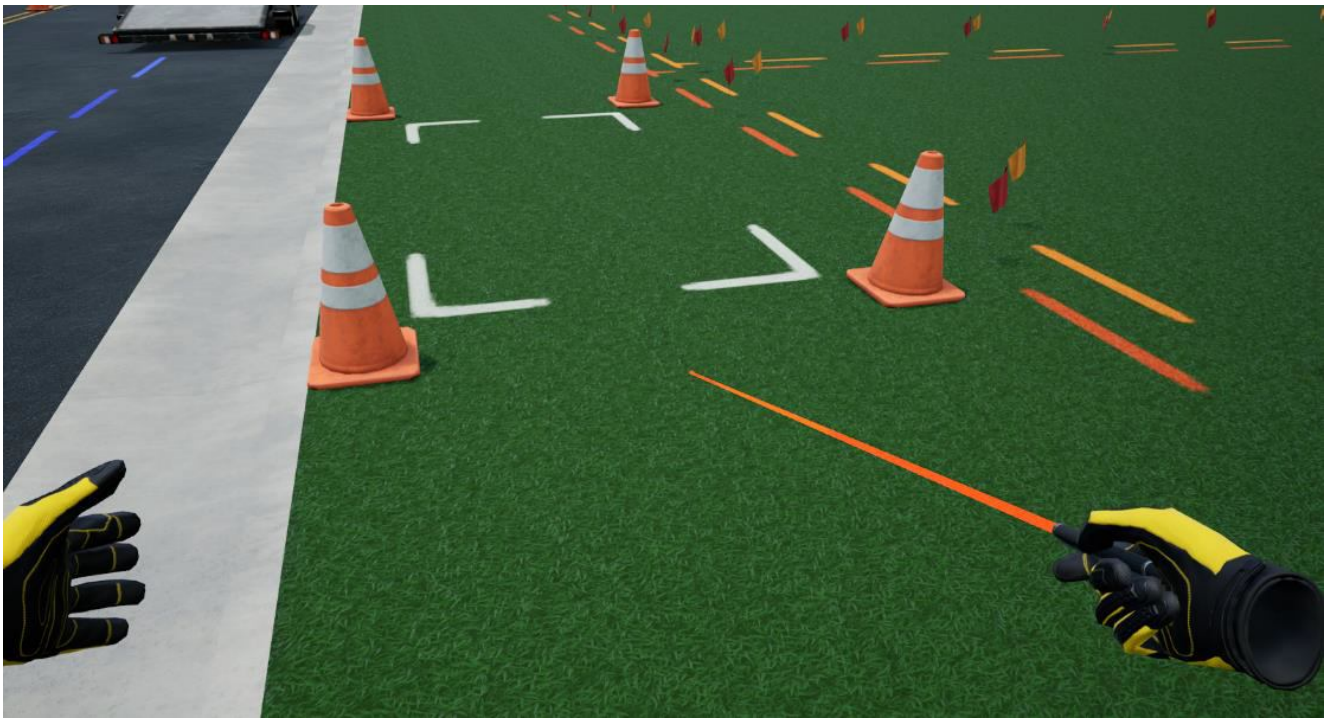
Phase 2 objectives are to design, develop, test, and maintain a VR training content-delivery system that meets the needs of the industry. The delivery system includes a control center for managing training content, administrator and user assignments, trainee performance data, and an authoring tool. In addition, a process for maintaining and enhancing current training content will be established as part of this project.

Deliverables

Phase 1 deliverables for this project include up to four realistic, interactive, computer-generated, immersive VR training modules on industry O&M tasks that can be used within the natural gas industry. Modules are built on familiar platforms and environments that allow for randomization and customization to be able to test critical thinking skills and knowledge of company-specific O&M procedures.

The deliverables for Phase 2 include:

- A Final Report that details the Control Center and Authoring Tool design, development, and testing.
- Training aids on the use of the Control Center and Authoring Tool.



A variety of modules are being developed.

- Coordination and facilitation of a VR Users Committee that collect information regarding the control center, authoring tool, and recommended current module enhancements.

Benefits

VR provides consistency of training and higher trainee retention rates to help reduce the business risk for an organization. Also, cost savings can be achieved through reductions in training class set-up time, training delivery (initial and remedial), and training completion (onsite or remotely).

The use of VR modules allows training to be conducted on demand by operations; increases the number of real-life training scenarios available for trainees to experience; reduces the risk of injury to trainees, trainers, and the general public on risky activities; and reduces the cost of instructor labor and materials for preparing traditional classroom and laboratory training.

As modules are customizable, the user can train on many random scenarios to grow their experience and critical thinking in a safe environment. Mistakes made in the modules will not be repeated on costly equipment and allow for continuous training without the need to set up and take down equipment or props.

Technical Concept & Approach

With sponsor input, the project team will develop a storyline and the VR environment in which the trainee will respond to a variety of scenarios. Project team members and sponsors will develop industry general approaches to responding to natural gas emergency situations.

The project team will identify and evaluate new VR hardware equipment that is compatible with the training library content. This evaluation will include tethered, wireless, and workstation-type VR hardware equipment.

A control center is being develop to handle content delivery, administrator and training assignments, and trainee performance data.

Results

In 2019, demonstrations were performed for staff to test reaction and user-friendliness of the VR hardware. Subsequently, onsite training and demonstrations were conducted for six project sponsors.

In 2020, module customization and testing was conducted. Project activities included providing continued VR evaluation and integration support to various utilities. In addition, enhancements were made to VR library training modules for delivery on a new platform. These enhancements include being able to download training content directly from a control center, being able to use all training modules on a wireless headset system, and the programming of all modules to allow multi-user functionality.

"Our students and instructors have praised the realism of the Natural Gas Leak Emergency Response training module. Whether the participant was a veteran employee or new to their role, they stayed highly engaged and got something unique out of it. One of the greatest values we have observed is the ability for the instructor to provide real-time feedback to the student as they navigated the scenario."

- Tristan Murray
Manager, Training Quality & Innovation
Atmos Energy Corporation

A trial VR Training Technology Evaluation Program was initiated. This program allows project sponsors and their organization to evaluate VR training technology without the initial investment of purchasing hardware equipment.

In 2021, alpha and beta testing were completed for various new VR training modules, including *Gas Handling* and *Stand-By Activities*. *Emergency Response Situations*, *Facility Locating and Marking*, *Pipeline Patrolling,Main Line Extensions, Main Line Abandonments,* and *Main Line Section Cutouts and Replacement*.

As for new VR training development projects, technology users identified the next two training modules for development. The first module is related to *Damage Prevention* activities and the second module will provide a *Distribution Systems Overview* for new engineers within the industry. Lastly, the project team started the evaluation of two new VR headset devices.

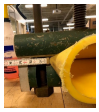
Status

This project team continues to update modules according to technology-user feedback collected during the annual maintenance review process. The team also continues to identify, collect, and communicate Control Center and Authoring Tool enhancements.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Polyethylene (PE) Squeeze Tool Gap Stop Evaluation



In this project, researchers are investigating requirements in an effort to develop a tool/ measuring device to verify that PE squeeze tools are within tolerance in relation to pipe and tubing when performing a squeeze operation.

Project Description

Squeeze tools used to stop the flow of natural gas in polyethylene (PE) pipelines are a very common equipment used every day in field situations. Operations include emergency stoppage, planned extension and abandonment of PE pipelines, and training and operator-qualification purposes. By flattening the pipe between two parallel bars, this squeeze-off provides an easy and quick shut-off of the line. However, improper squeeze-off can cause damage to the pipe, create a safety hazard, or both.

When performing a squeeze, a gap in the pipe may appear. If too large of a gap, the operator will not be able to obtain proper flow control or make a complete stop. Too small of a gap could lead to over compression of the PE pipe. After the squeeze tool is removed, the pipe is forced back to near round shape by internal pressure or may be mechanically re-rounded. In either case, a permanent deformation results and a stress concentrator is created.

To provide over-squeeze protection, squeeze tools come with mechanical stops, which are based on pipe diameter and wall thickness. Typically, the tool stops are set for 30% or less wall compression based on maximum wall thickness.

Utility personnel currently do not have tools to quickly check the performance of the squeeze tools. The use of a stop gap device as a calibration tool and/or validation tool before performing a squeeze on a PE pipe can lessen the risks associated with performing a squeeze improperly.

In this project, researchers are investigating the gap requirements to develop a tool/measuring device to verify that PE squeeze tools are within tolerance in relation to the PE pipe and tubing when performing the squeeze operation.

The resulting tool could be used to check new and used squeezers to verify if they are within the required tolerances. It could also be used during field operations to make sure the mechanical stop on the squeeze tool is set at the correct position.

Deliverable

The deliverables of this project will include:

- A Final Report that includes research findings on the gap stop measurements on new and used squeeze-off tools

Left: gap tool too loose. Right: gap tool too tight.

- The development of a series of validation/inspection tools to measure the gap stop of PE squeezers for various pipe diameters, and
- Recommended procedures on measuring the gap stop to determine if tools are within the recommended tolerances to perform a squeeze.

Benefits

A gap tool could be used by field personnel and inspectors to avert both immediate and potential long-term damage to PE pipes from improper squeezing of the pipe. This can be accomplished by verifying the correct distance between squeeze bars with a gauging device before the squeezer is put into use. This tool could be used to validate the gap for both new and existing squeeze tools.

Technical Concept & Approach

A project team reviewed ASTM standards for PE squeeze-off tools and various squeeze-tool manufacturers' literature to determine if and what formal process is in place for determining and checking the gap stops. Researchers also investigate various squeeze tools. This includes the inspection of currently used field tools at various utilities and the inspection of new tools direct from various manufacturers.

A measuring device (gap tool) is being designed, developed, and fabricated to meet the required gap allowance that the specification calls for various pipe sizes. Researchers will validate the gap tool and its capability to accurately provide a go/no-go confirmation in both the laboratory and in the field. Investigators will also send the tool to sponsors – along with recommended procedures – for validation and feedback.

Results

The project team compiled information regarding PE sizes used by project sponsors. This included creating a questionnaire for the OTD members.

Researchers developed conceptual squeeze-tool gap validation devices. Based on feedback, the team created 3D-printed squeeze-gap stop tools.

Research found that when the distance between the squeeze tool bars is greater than twice the wall thickness, the pipe walls are not compressed, which yields a negative value for the wall compression percentage. The project team developed the sizes (thickness) needed for each participating individual utility. These sizes are based on 30% or less wall compression based on maximum wall thickness (a distance that is 70% of twice maximum wall thickness when the squeeze tool is closed to the stops). By fabricating the gap stop tool to these tolerances, operators can verify that the squeezers are acceptable if fully closed to the stop.

Example of under-squeezed PE pipe.

It became apparent that there is little room to be able to insert the gap stop tool while the squeezer is in use. However, the gap stop tool still can be used as a quality check, such as for operator qualification, training, maintenance, and, if required, before actual use of the squeezer.

In 2021, a PE Squeezer Gap Tool Instructional Guide was developed for use when evaluating the gap tool prototypes on project sponsor's own squeezers.

Researchers tested the prototype gap tools on a wide variety of readily available squeezers, and documented the results with photos and notes to validate functionality. The process is as simple as closing the squeezer bar against the stops and inserting the appropriate segment of the gap tool between the squeezer bars. During squeeze-tool testing using the gap tools, all of the squeezer bars bottomed out against the corresponding stops with the gap tool fitting between the bars without being taut or without being lax. The outcome of all the squeezes made showed that the PE fully compressed to the point where you could not continue further with the squeeze operation.

Sample tools were sent to project sponsors. Discussions were held with various project sponsors to review feedback.

Status

Researchers are collecting questionnaires from all users of the gap tool. The project team and sponsors will determine next steps of the project.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Purging Gas Pipes into Service without Venting Gas to the Atmosphere

Research is under way to evaluate and enhance an alternative method to purge gas pipes into service with no or minimal gas vented to the atmosphere. This project includes an investigation into the economic, environmental, and social impact of vacuum purging as an alternative practice.

Project Description

Gas purging – a process of displacing one gas by another gas – occurs on a routine basis in the natural gas industry when pipelines are put into and out of service. Pipelines are purged to prevent the presence of a combustible mixture of gas and air. Failure to follow good purging guidelines and procedures may result in a serious incident and/or outages.

During the direct purge method for commissioning a new gas pipe, the air in the pipe is purged out of the pipe by introducing natural gas into one end of the system and venting the air, air/gas mixture, and finally natural gas from a open vent at the other end of the system. The venting will typically continue until gas readings at the open vent reach 95% natural gas or greater. This method has proven to be very effective; however, it may result in the venting of large quantities of natural gas to the atmosphere and contribute to a utility's annual carbon footprint. In this project, research is being conducted to find alternative methods of purging gas pipes into service to reduce overall methane emissions.

One alternative to venting the gas to the atmosphere is through the use of a vacuum pump. This process pumps the air out of the pipe to be placed into service. Once the proper vacuum level is reached inside the gas pipe, the vent is closed and the natural gas is introduced into the pipe without the need to vent.

Researchers are investigating a vacuum-purging procedure that eliminates trapped air without venting natural gas into the atmosphere during pipeline commissioning by using the correct vacuum-pump capacity. This also results in time improvement compared to traditional purging procedures.

This project includes an investigation into the economic, environmental, and social impact of this alternative practice. Vacuum-purging guidelines will be developed as part of this project effort.

High-priority issues being addressed include:

- Development of safety features/protocols to detect the presence of natural gas through the system and stop the operation
- Further demonstrations of the solution, and
- Development of the necessary fittings and components for a natural gas utility company to acquire and operate such a system off the shelf.

Deliverables

This project will provide comprehensive reports that describe the current vacuum-purging practice to minimize the venting of natural gas to the atmosphere. The reports will cover:

- Market drivers and environmental impacts
- The current effects of venting blowdown gas to the atmosphere
- A cost analysis of implementation of alternative methods that includes environmental impacts of these methods, and
- Guidelines/equipment needed to implement the vacuum-purging system.

Benefits

Minimizing or eliminating the current practice of venting natural gas to the atmosphere during purging can help reduce methane emissions.

Technical Concept & Approach

The current system is assembled from various commercially available components. For broader acceptance and implementation, a vacuum-purging packaged unit is needed that may include a vacuum-pump system with integrated methane-detection alarms and safety shutoff; incorporated flame arresters in the exhaust outlet; and appropriate hoses, connectors, purge stacks, etc.

The final system will need to include sensing components that allow for the monitoring of the methane concentration inadvertently pulled through the vacuum. This task will include identifying, acquiring, and testing these components to ensure that they perform as required and operate safely with the vacuum system.

Once the field-ready version of the vacuum system is configured, researchers and project sponsors plan to conduct live demonstrations at utility-sponsored sites. These demonstrations are designed to identify operational and component issues as well as introduce the technology to the project stakeholders. A user's manual for the system's safe operation and use will be developed.

Results

During the Phase 1 effort, the project team obtained a replica vacuum system that is currently being used in the industry. Researchers also constructed a test loop with pressure-sampling capabilities to observe the effects of vacuum conditions on a distribution network and various operational parameters of the vacuum system. This allowed for a better understanding of the operation, performance, and areas for possible improvement of the current system.

Numerous pump-downs on pipes were conducted to evaluate the efficacy of such a system on various pipe volumes. The system fully removed all measurable air molecules from the pipe samples tested (up to 800 feet of four-inch diameter polyethylene pipe), showing that 100% pure natural gas can be introduced to the system without the need to vent any gas to the atmosphere from a purge and that the vacuum purge is a viable concept for continued evaluation.

A Phase 1 Final Report was issued in November 2020.

In 2021, the research team completed the test loop of PE pipe in the a pipe farm. The system also contained various valves, utility purge fittings (tapping tees, end fittings, etc.), and purge stacks for various evaluations and verifications of the no venting purging operations.

In August, the team used the first prototype vacuum system to conduct various trails. First, pulling the system to various vacuum levels and timing the operations when using various types and sizes of fittings to connect the vacuum pump system. The operation took approximately 14 minutes to bring the entire system down to -14.5 psia. Which at an of approximately elevation of 660 feet is assumed to be near a complete vacuum. After several successful vacuum purges, the team then introduced natural gas into the system.

The team conducted a live demonstration of the vacuum-purging operation of the pipe in the pipe farm. This live demonstration was also successful at achieving a complete natural gas purge without venting gas to the atmosphere.

A new vacuum system was received in November. The project team was required to make some additions and modifications to the new unit, including adding a power supply and also reconfiguring the frame of the cart system in order to make it more maneuverable.

Various-sized excess flow valves (EFVs) were installed on each service pipe. During testing it was initially observed that drawing vacuum downstream of the main on a service line did not trip the EFV, but allowing air or gas in from the mainline side did cause closures in two cases (lower capacity EFVs). However, the by-pass automatic valves reopened quickly after the pressure differential slowly decreased. Further evaluation will be needed to better understand how the tapping of the tee (introduction of natural gas from the main) may have an impact on the EFV.

Status

Two additional service tees, PE tubing, and different capacity EFVs are also being added for further evaluation of the vacuum purging process. The team will also evaluate the full process of purging each service line, create the vacuum from the riser and then tap the tee with 60 psig pressure. This will allow the team to fully understand the performance of the EFVs and determine if false closures occur.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Evaluation and Demonstrations of the Utonomy Smart Regulator

In this project, researchers are conducting a technical review and evaluation of a smart regulator for medium- and low-pressure gas distribution systems. The system is designed to provide operators with visibility and pressure management as well as remote control of pressure-regulator output of their regulator stations.

Project Description

District governors regulating the pressure in natural gas distribution systems are manually adjusted on a seasonal basis two to four times per year. They are set to the maximum pressure that is anticipated to be needed to satisfy the highest gas-delivery demand for the required period of time. The set-point pressure takes into account factors that will drive up gas usage, such as the time of day – typically, the early morning hours, a very cold peak heating day, etc.

Some systems have remotely monitored and controlled pressure regulation, but company personnel must operate these systems 24 hours a day. Low-pressure systems, where the pressure regulator can be a significant distance from the end of the distribution network, must also take into account the slower response time of the system to an increase in regulated pressure. Pressure adjustments may need to be made sooner and possibly at a higher set point to maintain the minimal operating pressure at the end of the system. This means that for the vast majority of the time, the set operating pressure is significantly higher than is needed. This leads to higher gas leakage and larger lost and unaccounted for gas than would be experienced if the pressure were autonomously adjusted remotely and automatically in real time as needed to meet changing gas demand, or by a system that could predict pressure requirements and make regulator adjustments before the need is detected.

There is also growing environmental concerns for the effects of greenhouse gases on the global environment. Gas companies are under growing pressure to decrease fugitive natural gas emissions through better control of the gas distribution system and the sources of natural gas leakage.

These issues could be addressed through the development and implementation of a system that would automatically regulate the pressure in gas distribution lines in real time. Increases in system pressure through automatic adjustment of a gas pressure regulator would only occur during times of increased gas demand, while maintaining lower pressure during periods of low demand.

This project focuses on the Smart Regulator system, which was developed in the United Kingdom by Utonomy, Ltd., in 2015. The Smart Regulator is an innovative active gas utility pressure-management system that uses a combination of hardware- and software-based self-learning algorithms and remote-controlled actuators to control system pressure in real time. The system allows operators to regulate system pressure to the lowest possible pressure while meeting system-delivery requirements, thus reducing gas leakage and unaccounted levels.

In Phase 1 of this project, case studies of pilot installations and an evaluation of the Utonomy system were performed. The objective of Phase 2 is to demonstrate the operation and benefits of the Utonomy Smart Regulator through testing laboratory testing and in North American utility field trials.

Deliverables

The deliverables of this project will include a report that 1) compares commercially available systems that remotely and autonomously control gas pressure regulator operations 2) details the results of the Utonomy Smart Regulator laboratory testing in a simulated field environment 3) provides a case study detailing the

the results and experience with the Utonomy Smart Regulator, 4) describes site visits, installations, implementation, and operation of the Smart Regulator, and 5) the in an operating field, and results of field demonstrations.

Benefits

The Smart Regulator is designed to be retrofitted to existing gas distribution regulators and pressure control systems so that it can be applied to a range of current gas pressure regulation systems.

Benefits include:

- The ability to remotely or automatically adjust the pressure output of a pressure regulator station several times per day in response to changing gas demand through the day
- Elimination of the need for gas company personnel to frequently visit each pressure regulator station to make these adjustments
- A reduction in the loss of gas from the system
- Remote visibility of the operation of regulator inlet and outlet pressures
- A reduction in reports of gas odors in the controlled network
- Improved pressure stability in the network, and
- Easy installation.

Technical Concept & Approach

This project includes a review of customer needs and development of a laboratory and field-testing approach.

Researchers will conduct a high-level study of similar technologies that may be available.

Fitness-For-Purpose testing will be conducted. This will include the design and construction of a small-scale gas distribution piping system that can be pressurized to different levels and flow rates. The Smart Regulator system will be installed on this laboratory piping system to evaluate its communication, analysis, and response to simulated changes in system gas delivery requirements. This will include establishing a cloud-based communications platform and data-logging capability. The project team will test the system's ability to retrieve instructions from the platform and return data and status information. An evaluation will be conducted from a cybersecurity aspect.

The project team will coordinate field demonstrations of the Utonomy Smart Regulator. The field demonstration will be conducted over a period of 12 months to allow evaluation of its operation and response to seasonal load variations.

Results

A technical review and evaluation of the Utonomy Smart Regulator was performed to better understand the capabilities, benefits, and possible transference to the U.S. natural gas industry. The team obtained detailed information on the Utonomy system and functionality. In addition, the team conducted a visit to Utonomy to examine the system and all the various components and user interface software. The team also visited a large gas network operator to discuss its evaluation and pilot installation of the Utonomy system. In addition, the team visited a district regulator station that was enhanced with the Utonomy system.

The Utonomy Smart Regulator is currently in operational field trials at five locations in the southern U.K. All five locations use identical components and regulator stream configuration. The only variations are the make and model of the main regulator used and the size of the components. All five pressure regulator kiosks are above ground prefabricated structures. A larger field deployment was initiated in the U.K. that includes below-ground regulator structures.

In the current Phase 2 of the project, the team reviewed the latest developments, approvals, and implementations of the Utonomy Smart Regulator. Following testing of the revised Utonomy Smart Regulator system (actuator and controls), the plan will be to move forward with North American field trials.

As part of efforts to ramp-up the design of the adaptors, Utonomy is looking at the relevant North American safety codes and regulations that apply to regulators.

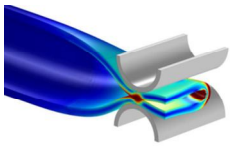
Status

Utonomy plans to make updates to the actuator and other smart-regulator components to allow for adaptation to regulators used in the pilot program.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Best Practices for Squeeze-Off of Vintage Polyethylene Pipe



Specific guidelines and best practices are being developed for performing squeeze-offs on vintage polyethylene pipes. Research is being conducted on the ability of various repair clamps/fittings to reduce stresses on vintage PE pipes after squeeze-off operations.

Project Description

Gas utilities are aware of the potential damage that an improper pipe squeeze-off operation can impart on polyethylene (PE) pipe. In this project, research is being conducted to determine the probability of imparting damage in pipes and fittings in close proximity to a squeezed-off point and provide data, recommendations, and best practices (e.g., use of clamps for protecting the squeezed-off location) for performing a squeeze-off operation.

This method being developed is based on the results of OTD project 2.13.d, *Method for Developing an Initial Risk Profile for Aldyl-A Piping Systems*. A specific task under the project evaluated the expected residual lifetime of vintage Aldyl-A piping after squeeze-off with and without the use of a reinforcing clamp/fitting.

Several other projects were conducted also investigating the performance and life expectancy of vintage PE pipe, including an investigation to forecast the remaining useful life and pressure-carrying capacity of vintage Aldyl-A pipes, taking into account the effects of:

- Specific field temperatures and other conditions
- Rock impingement
- Soil loading and earth settlement
- Pipe bending, and
- Squeeze-off.

Deliverable

This project will provide information on the ability of various repair clamps/fittings to reduce stresses on vintage PE pipes after squeeze-off operations. Testing reports detailing the performance of the various clamps/sleeves will be provided in a Final Report.

Benefits

Squeeze-off is a technique used to stop or reduce the flow of gas in PE pipe by compressing the pipe between parallel bars until the inside surfaces of the pipe make contact. This operation has been shown to inherently induce damage at the squeeze-off. A method to protect gas pipes at the squeeze point by using specific repair clamps/fittings that are currently available in the market could potentially enhance and extend the lifetime of a squeezed pipe.

Technical Concept & Approach

The project team is building on research carried out in previous projects and further investigating and quantifying the stresses imparted on a PE pipe as a result of the squeeze-off procedure. In addition, researchers will evaluate the extent of imparted damage, and develop guidelines and best practices for maintaining the life of squeezed-off vintage PE pipes.

The approach is to employ Finite Element Method (FEM) analysis to determine the Stress Intensification Factors (SIFs) induced by the squeeze-off operation on various pipe sizes and materials. The SIFs will then be validated using 3D X-ray computed tomography (CT) scanning.

Various replacement clamps and fittings will be evaluated.

Specific tasks include:

- **Specimen Acquisition**

  Samples for testing include medium-density and high-density PE pipe samples and corresponding stainless-steel repair clamps, various electrofusion encirclement fittings, and butt-fusion repair sleeves.

- **Squeeze-off, CT Scanning, and FEM Analysis**

  Researchers will validate the kind of damage that is imparted in squeezed-off pipe. This will be accomplished by performing pipe squeeze-offs at 0°C, 23°C, and 40°C (32°F, 73°F, and104°F) in accordance with ASTM F1041 and D2513 under typical operating pressures. For each pipe size, multiple specimens will be prepared at each temperature. One sample from each temperature will be sent for 3D CT scanning before squeeze-off. On completion of the squeeze-offs, all of the specimens will be CT scanned. The acquired 3D scans will be used to generate CAD models. The generated CAD models will then be used to simulate pipe internal pressurization via FEM analysis to determine what the local SIFs are for various pipe sizes after they have been squeezed-off. This will generate absolute values of SIFs due to geometric deformation. The results will be compared to those of squeezed-off pipes in an historical database. This reference data will enable the team to provide lifetime prediction of squeezed-off pipe evaluated in this project.

  The CAD models from before squeeze-off will also be used in full squeeze-off simulation and the deformation results will be compared to the CT scanned deformation. This will help verify the simulation and provide insight about the damage induced by the squeeze-off process.

- **Material Properties Testing**

  To support the FEM analysis, material properties testing will be performed via tensile testing and Dynamic Thermo-Mechanical Analysis. For each pipe material, three replicate specimens will be tested at three temperatures. Two pipe materials will be tested.

- **Short-Term Validation Testing**

  In this task, the squeezed-off pipe samples that were 3D scanned will be prepared and tested. A total of 36 specimens for each pipe size/material combination will be tested. The squeezed-off and clamped pipe specimens will be subjected to elevated temperature sustained hydrostatic pressure testing to validate a desired lifetime at end-use operating conditions.

Results

In 2020, initial project activities included a survey to gather information from the sponsors. The objective of the survey was to identify needs with regards to the size and type of repair clamps needed to protect the squeezed-off location of vintage polyethylene pipes.

Researchers obtained quotations for procurement of five selected clamps. The project team performed an inventory of on-hand Aldyl-A pipe samples to initiate the testing based on this material.

In 2021, the research team requested pipe samples from project sponsors. Unfortunately, only one company provide samples.

Squeeze-off, 3D CT scanning, and FEM analysis was initiated using Aldyl-A pipe samples.

Status

Sponsors are being contacted to provide the following pipe samples:

- 2″ IPS pre-1983 Aldyl-A
- 2″ IPS pre-1995 HDPE, and
- 2″ M7000/M8000.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Emergency Leak Tool for Stopping Blowing Gas

The goal of this project is to provide a market-ready leak clamp tool that can be used to quickly, safely, and effectively stop off a gas leak from outside of the same excavation or opening.

Project Description

In a natural gas emergency involving a leak, typically additional openings are excavated away from the damaged leaking pipe to stop the flow of gas to the pipe section that needs repairs. In these additional openings, crews perform stopping operations, squeeze-off, or tapping and stopping to stop off the flow of gas to the leak. Upon successful completion of securing the gas, the damaged section of pipe is repaired or removed from service and a new segment installed. This repair process takes a significant amount of time and can result in a long duration of the uncontrollable release of gas and possibly service interruption to customers.

The goal of this project is to provide a market-ready leak clamp tool that can be used to quickly, safely, and effectively stop off a gas leak from outside of the same excavation or opening.

Deliverables

The deliverables for this project include:

- A field-tested product produced by a third-party manufacturer prepared to commercialize the tool
- Generation of a commercialization agreement with a third-party manufacturer and distributor, and
- A Final Report describing the improvements of the design and testing results of the final product.

Benefits

Having an emergency leak tool to stop blowing gas from outside of the trench will allow utilities to stop an active gas leak in a safe and more efficient manner. This tool will improve employee and general public

"The development of an emergency tool to stop blowing gas from damage to our natural gas infrastructure is a perfect example of a project life cycle that begins as a member problem. The problem reaches conceptual maturity and then grows to full prototype development in OTD."

- Rick Trieste
Dept. Manager R&D
Consolidated Edison Company of New York

safety by reducing the amount of time required to secure the uncontrollable release of gas as a result of third-party damage. Also, due to the reduced time of blowing gas, this will reduce the amount of methane emissions released into the atmosphere. There are also potential labor, equipment, and restoration savings by eliminating the need to dig additional excavations to squeeze-off or stop-off the pipe away from the blowing gas location.

Technical Concept & Approach

Specific tasks include:

- **Design Refinement of the Tool**

  This task includes interactions with manufacturers to refine the design of the external clamp prototypes such that it is stronger, more effective, and can be easily fabricated by the manufacturer. Currently, the leak clamp prototypes are designed to stop the flow of gas on polyethylene (PE) and steel pipe sizes of two inches in diameter through eight inches in diameter.

- **Fabrication of the Final Tool Design**

  This task will mostly be conducted by the manufacturer to fabricate the final external clamp tool with oversight by the project team to ensure tool requirements are met.

- **Laboratory and Field Testing of the Tool**

  This task includes laboratory testing and field testing the fabricated clamp tool by the manufacturer and testing it on damaged PE pipe and steel pipe. This testing will include multiple-size clamp tools and the different design enhancements made during the fabrication process.

- **Commercialization**

  This task includes efforts to bring this product to market, including, but not limited to, protecting intellectual property and seeking patents, obtaining a distributor, and securing licensing agreements.

Results

In 2020, the project team received prototypes for testing from two manufacturers. The first tool used two hydraulic cylinders. For the second tool (which used a long-lever arm), the project team performed testing on various gasket materials, thicknesses, durometers, and shapes to determine the type of gasket that would provide the best seal given the design of the cavity. Researchers found that changes were needed to be made on the long-arm clamping mechanism and the method of adhering and capturing the seal on the main body.

The project team and manufacturer of the lever-arm concept developed a new clamping method involving a lead screw on the lever arms. For the other prototype, the project team refined the design of the hydraulically-activated leak clamp. The project team has gone through two major design revisions for this method. The second redesign uses a single hydraulic cylinder to lock the teeth around the pipe and then push the seal into the pipe and locked teeth at the same time.

In 2021, researchers tested the mechanical leak clamp prototype on a four-inch-diameter PE Pipe buried under three feet of clay soil, which will be punctured by an excavation machine. New cavity body manufacturing and testing were conducted. The mechanical leak clamp prototype was modified with a large elastomer seal that fully plugs the leaking hole. This prototype is activated by turning a crank handle which closes clamp arms around the bottom of the pipe to draw the seal into the leak in the pipe. This prototype was tested on five different styles of pipe damages (artificial slot, true puncture, artificial flap, overhanging artificial flap, and out of round) in a laboratory setting at high pressures (60psig – 100psig). The leak clamp sealed all of these puncture styles up to 60 psig, and certain damages were sealed at up to 90-100 psig.

Due to the success of the prototype, the project team decided to cease development of the single-hydraulic clamp prototype to focus the efforts into the mechanical leak clamp prototype.

Status

Following testing, the prototype will be sent to a select number of sponsors to for input before the final commercialized version of the product is made.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Over-Pressure Protection Options for Low-Pressure Gas Distribution Customers

Researchers are identifying and evaluating over-pressure protection options available for the natural gas industry for low-pressure gas distribution customers. Gas pressure regulator manufacturers are being engaged in development efforts to enhance current designs to meet industry needs.

Project Description

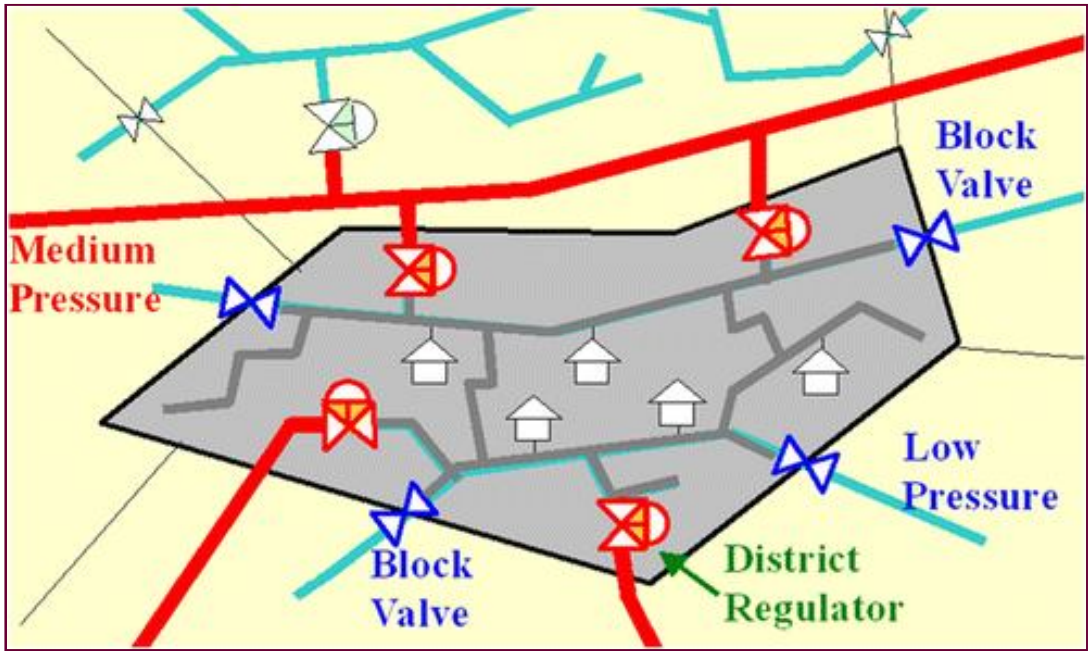
After experiencing an over-pressurization incident of a low-pressure gas distribution system, the natural gas industry has begun to reassess on how this type of incident can be prevented in the future.

Researchers find that low-pressure gas distribution systems are vulnerable to over-pressure situations for multiple reasons:

- Abnormal operation of regulator stations that may allow pressures to rise above set pressures
- The total number of regulator stations that may be controlling one area of a low-pressure system with dozens of pressure-sensing lines controlling system pressure
- The opportunity for errors in cross-connections with the large amount of new infrastructure being installed, connected, and disconnected from low-pressure systems
- Personnel that are unfamiliar with unique operating characteristics of low-pressure systems and may not be able to identify a potential failure before it occurs, and
- The decreasing knowledge and experience levels of personnel due to most of the new pipe installed over the last 30 years having been steel and polyethylene piping at higher operating pressure and pressure regulation at each user.

Low-pressure gas distribution systems will be in existence for the next 30-plus years based on the inventory of pipe remaining and the difficult-to-upgrade locations in which they are located. The safeguards put in place today will help to prevent future failures.

In this project, researchers are identifying and evaluating over-pressure protection options available within the natural gas industry for low-pressure gas distribution customers. This project will also engage gas pressure regulator manufacturers on possible research and development efforts to enhance current designs to meet industry needs (e.g., increasing flow capacity, having the ability to regulate minor over-pressure fluctuations, and minimizing the pressure differential through the device). In addition, a reference guide will be created for use when considering which type of over-pressure protection option to install on the end of low-pressure service lines to improve overall system integrity.



Deliverables

The deliverables for this project will include:

- A Final Report detailing the technical specifications for the different over-pressure protection options for low-pressure gas distribution service
- Coordination and facilitation of webinars with manufacturers (including potential new products), and
- A report that will include a reference guide comparing similar over-pressure protection options for each of the different manufacturers.

Benefits

Installing an over-pressure protection device (OPPD) on low-pressure gas lines to serve customers reduces risk in the event of an unintended system over-pressure situation that may be the result of a mechanical failure or human error.

Installation of OPPDs will prevent widespread catastrophic failures in the event of an over-pressurization of the system. If OPPDs are not installed and a system over-pressure event occurs, the cost of third-party claims related to emergency response, personal injury claims, property damage, temporary housing, and legal fees can exceed $1 billion.

Technical Concept & Approach

Specific tasks include:

- **Identification and Evaluation of Over-Pressure Protection Devices for Low-Pressure Service**

  This task includes the identification and evaluation of current over-pressure protection options for low-pressure gas distribution service to customers. The evaluation includes the technical specifications of each device. A reference guide will be prepared with this information comparing similar devices and options. In addition, regulator manufacturers will be interviewed on the level of research and development efforts for OPPDs currently under way or expected in the near future.

- **Regulator and Device Manufacturer Webinars**

  This task includes the coordination and facilitation of webinars for each of the regulator and device manufacturers to present on their over-pressure protection offerings for low-pressure gas distribution customers. One webinar will be conducted for each of the manufacturers. These webinars will be recorded for those unable to participate and the manufacturer presentations made available to project sponsors.

Results

The over-pressurization incidents investigated by the National Transportation Safety Board (NTSB) over the past 50 years demonstrate that low-pressure natural gas distribution systems that use only sensing lines and regulators as the means to detect and prevent over-pressurization are not optimal to prevent over-pressurization incidents. The NTSB recommended to "revise Title 49 Code of Federal Regulations Part 192 to require over-pressure protection for low-pressure natural gas distribution systems that cannot be defeated by a single operator error or equipment failure."

Activities for this project included identification of the project team, conducting a project kick-off call with sponsors, performing a search of existing products, and speaking with industry subject matter experts on available products.

Status

This project is complete. A Final Report is pending.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Identify and Validate Best Practices for Applying Heat to Steel Near PE Materials

For this project, a research team is developing a best-practices guideline for operations that apply heat to steel components near polyethylene (PE) pipe, with respect to preventing overheating of the nearby PE system components.

Project Description

Currently, there is no industry guidance addressing the application of heat to steel pipes and components (that are upstream of PE pipe and components) to minimize the risk of potentially overheating the PE pipe and fittings.

The objective for this project is to develop a best-practices guideline for applying heat to steel pipelines near PE materials.

The phenomenon of heat transfer needs to be studied in the context of operations on steel pipe where heat is applied (e.g., welding). Such applications include heat transfer by conduction through the pipe and fittings and heat transfer via convection from internal air/gas flow. The heat transfer via these mechanisms is generally dependent on the duration of the heating, internal air/gas temperature and flow rate, temperature of the pipe, ambient temperature, and wind speed.

Heat transfer to pipe and components downstream of the location of heat application will also depend on the specific geometry of the piping system, including internal pipe diameter, wall thickness, bends, and any flow-stagnation points.

Deliverable

The deliverable for this project will be a best-practices guideline for applying heat to steel components near PE pipe, based on the scope of the investigation.

Benefits

Establishing best practices for applying heat to steel components near PE pipe could help reduce operational risks associated with excessive heating of PE pipe/components (which can lead to short-term creep rupture).

It is anticipated that these best practices can be applied to welding operations in the vicinity of PE piping systems (welding transition fittings, stopper nipples, gauge tees, etc.).

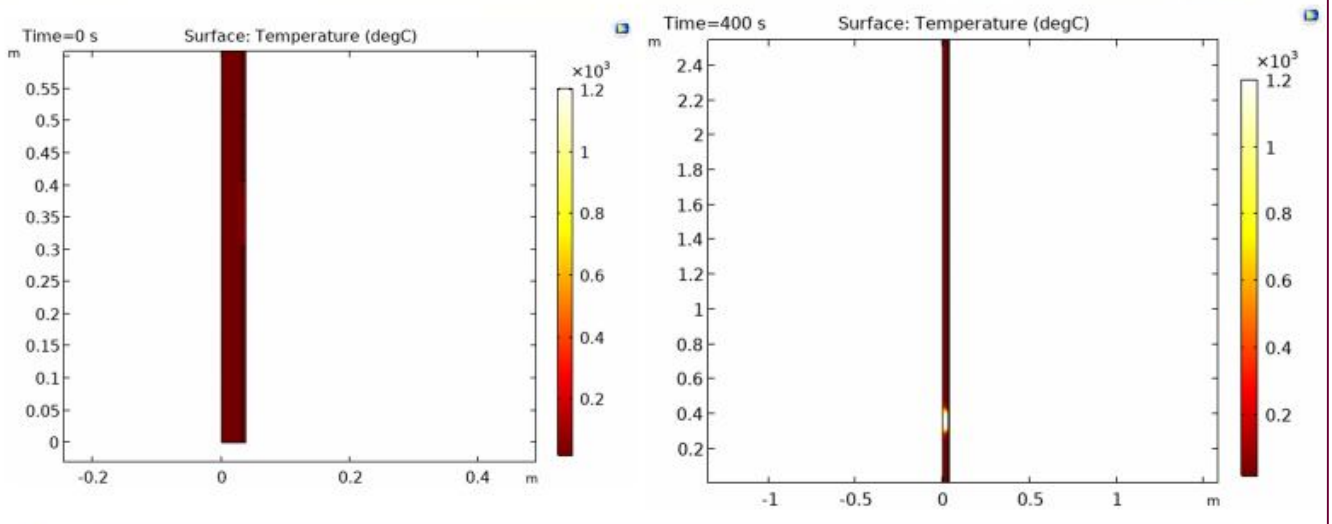
Technical Concept & Approach

Specific objectives for this project are to:

- Identify realistic field conditions to maximize the efficiency of the project
- Determine the materials of interest and if material testing is needed, and
- Discuss execution of validation testing.

If existing material data is deemed insufficient, the materials of interest (steel and PE) will be tested for their heat-transfer properties – thermal conductivity and heat capacity – to ensure accurate simulations. Simulations will determine how long it would take for PE components to become overheated under various conditions.

One or more of the worst-case scenarios will be physically reproduced and evaluated to validate the simulations. If appropriate, validation testing may be performed at one of the project sponsor's facility.



Heat transfer analysis.

Results

This project focused initially on the development of a parametric simulation model and conducting preliminary analysis based on inputs such as welding procedures and field-condition data. A conjugate heat-transfer analysis was carried out and the resulting temperature responses at the steel-plastic pipe interface analyzed as a function of distance between the heat addition zone and plastic pipe and gas flow rate.

A welding simulation study was carried out to determine the spatial influence of welding/heat application and a parametric axis-symmetric model was developed to study the heat-application impact on the steel-plastic interface.

A coupled heat-transfer Computational Fluid Dynamics model simulates heat addition to steel section without flow and subsequent to heat addition gas flow at 250 standard cubic feed per hour (SCFH) to study the impact of a hot slug of gas on the plastic-pipe section. The initial assessment indicated a marginal 10% increase from ambient temperature in temperature at steel-plastic interface at gas flow rate of 250 SCFH .

In 2021, activities focused on developing a stand-alone heat-transfer calculator that is underpinned by the conjugate heat transfer multi-physics model. This will aid field personnel in making assessments of heat transfer during hot squeeze and welding operations on steel pipes that are connected to plastic pipes at a certain distance downstream from the heat-addition spot. The user interface of the calculator will take welding/heat input parameters, pipe dimensions, local field conditions as inputs, and displays maximum temperature at the plastic-steel pipe interface as the response (in addition to graphical representation of the 3D model).

Researchers found that during the heat-addition phase there a negligible rise in temperature at the steel-plastic interface is observed. After the heat-addition process is completed, the flow of gas resumes and the temperature at the steel-plastic interface area increases by about 3%, whereas the reduction in temperature at the heat source area is 65% during the same time period of 40 seconds. This is due to the slug of hot gas that was heated during the weld process flowing downstream and heating up he downstream steel and plastic piping, while the flow of upstream gas, which at ambient temperature, cools the weld/heat source area by transporting heat downstream.

Heat-transfer simulation was pwed with a primary aim of verifying the physics behind the model. The scenario simulated assumes a two-inch-diameter pipe section with an overall length of 3.5 feet, of which two feet is steel and 1.5 feet is plastic.

Status

The research team continues simulation by incorporating additional feedback received from sponsors

Next steps include re-organizing the inputs and outputs based on procedures so that it provides intuitive sense to the end user. Other enhancements will focus on font size, report generation, and other requirements.

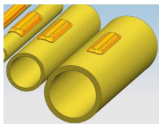
The research team is in the process of procuring the materials required to set up and conduct the validation testing.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Subsurface Multi-Utility Asset Location Detection

Efforts are being made to develop an intrinsically locatable polyethylene (PE) pipe that would be easy to locate with low-cost instruments. This project focuses on the necessary enhancements and industry implementation to current technology.



Project Description

Natural gas system operators are increasingly using plastic pipe due to its lower cost, longevity, and lower risk for corrosion. While there are many advantages of plastic pipe, the potential difficulty in locating polyethylene (PE) assets is a risk that could be mitigated with new technologies to make plastic pipe intrinsically locatable.

There are a variety of methods used to locate plastic pipe. The most common technique is the use of a tracer wire (coated copper wire) installed alongside the plastic pipe. While tracer wire is usually effective, there are several limitations. Other technologies, such as ground-penetrating radar, can potentially locate plastic pipe, but can be costly, cannot discern one utility from another, and may have disadvantages in certain soil types.

The main objective in this project is the development of an intrinsically locatable system, readily detected in normal field conditions without the need for additional costly equipment.

Field testing.

The research team successfully developed an integrated electronic marker to provide locatability to coiled or stick plastic pipes for gas and other utility applications, with a variety of sized plastic pipes. During the initial phase of research, the team identified the necessary follow-on activities related to this new technology. Efforts focus on optimizing the attachment process and enhancing the performance of the marker and locator towards greater burial depths.

An intrinsically locatable system would allow the pipe to be directly located with low-cost technologies similar to those used for steel pipe. A marker attached by the plastic pipe manufacturer at the time of production removes most of the risks associated with current methods of locating plastic pipe. It also provides a method impervious to different soil types, environments, and installation methods such as open trench, plowing, directional drilling.

Deliverables

The project is aimed at delivering a pre-commercial product for implementation at selected utilities. Other deliverables include an analysis of optimized electronic pipe markers, an assessment of plastic pipe production, and laboratory testing. The project team will also develop installation and operator training guidelines and videos with digital learning tools to ensure knowledge retention and increase operator training capability.

Benefits

The inability to accurately locate pipes can lead to increased risk to personnel and assets, increased time and costs associated with locating, and the risk of third-party damages. Installing plastic pipe with on-pipe markers to identify the pipe and nodes of interest with radio frequency identification markers and recording the installation with high-accuracy GPS will enhance the pipe location data integrity.

Advantages of an intrinsically locatable plastic pipe include:

- Enhanced safety for natural gas distribution net-

- Ability to locate the pipe is not affected if it is cut or damaged
- The electronic markers are not subject to inference from nearby utility lines
- Saves steps during installation – eliminates tracer wire and related installation, splicing and access
- Saves steps during location – eliminates transmitter connection
- Unique frequency for various utility pipes and conduits
- Eliminates susceptibility to lightning from a long conductor laying on the pipe, and
- Long life expectancy of product designed to last the lifetime of the facility.

Technical Concept & Approach

Initially, utilities and a newly formed Technical Advisory Panel were surveyed to better understand the needs regarding locatable plastic pipe and the implementation of this new technology. A testing matrix will be developed to assess the manufacturing process. The range of climatic conditions and soil types along with mapping best practices will be scoped. The utilities will also be solicited for field installation sites and an understanding for mapping and training needs. The manufacturer will then optimize electronic pipe markers and an above-ground locator specific to the needs of the program.

In collaboration with the pipe manufacturer and various attachment manufacturer(s), the team will develop and test methods to attach the electronic markers to the pipe. The pipe manufacturer will review current plastic pipe extrusion methods to understand necessary upgrades to processes and equipment for the attachment of the electronic markers to the pipe. Trial extrusion pipe runs will be conducted to validate the attachment method as well as any required process changes for the pipe coiling, loading, storage, and transportation. The output of this task will be a developed manufacturing guideline to produce the prototypes of the pipe and marker system for in ground testing and evaluations.

Various testing of both the marker and the attachment of the marker to the plastic pipe will be conducted. This testing will assist in developing a robust quality-assurance document and test procedures.

Testing of the markers and marker attachments may include but is not limited to the following:

- Tag frequency and aging drift evaluations
- Tag detection depth
- Attachment adhesion/bonding strength
- Creep analysis of the attached tag and the effects on the plastic pipe, and
- Installation environment considerations.

The team and participating utilities will develop installation and mapping guidelines and locator training guidance to support installations. In addition, the team will make efforts to install larger quantities of the intrinsically locatable pipe.

Results

In 2020, project sponsors stated that they want to receive locatable PE pipe with tags pre-installed. The sponsors also indicated that there may be certain situations where it would be beneficial to be able to install tags on the pipe in the field – this includes on existing pipe that is exposed and new installations at offsets and changes in direction.

A large PE pipe extruder agreed to partner with the project team on the project.

In 2021, the research team reviewed the project plan and finalized the development of the strategy and needs by each team member. The team continued working on optimization of the electronic pipe markers and enhancing the attachment methods for the markers to the PE pipe.

During Phase 1, the team validated the taping of the markers to the PE pipe for pipe two inches in diameter and smaller. However, the pipe manufacturer involved in this project notes that this will have a detrimental impact on its production facility and the overall efficiency of producing this smaller-diameter pipe. The company prefers to have a heat-fused attachment method. However, the current tags, due to their overall size, will not accommodate heat fusion to the smaller-diameter tubing.

It was determined that the taping method was a faster process and, therefore, more appropriate for the higher-speed production of the smaller-diameter tubing.

Status

The project team continues to review the marker attachment methods and are making efforts to identify a solution for the smaller-diameter pipe.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Procedures for Selecting Locating and Excavation Technologies

Researchers investigated technologies and decision-making tools for preventing excavation damage based on site and operation characteristics. The project focused on providing excavators, municipal decision makers, and the public with the most current knowledge on preventing damage to infrastructure.

Project Description

Federal and states' requirements and standard practices aim at preventing excavation damage to the natural gas infrastructure. These efforts include improving locating and excavation-monitoring technologies and enforcing one-call policies as the first lines of defense against excavation damage. Despite these efforts, excavation damage is still the leading cause of pipeline failure incidents. Approximately 31% of incident records in gas distribution systems are caused by excavation.

While many variables impact the safety of a digging project, the root causes of damaging utility lines start with the failure to make notification calls before digging. When calls were made, many of the locating practices failed to identify many of the below-ground facilities. When facilities were correctly located, a significant 52% of the failures were associated with poor excavation practices around the utilities.

The investigation of these root causes identifies several challenges to damage-prevention efforts. In this project, researchers investigated technologies and decision-making tools for preventing excavation damage based on site and operation characteristics. The project focused on providing excavators, municipal decision makers, and the public with the most current knowledge on preventing damage to infrastructure in the shared underground.

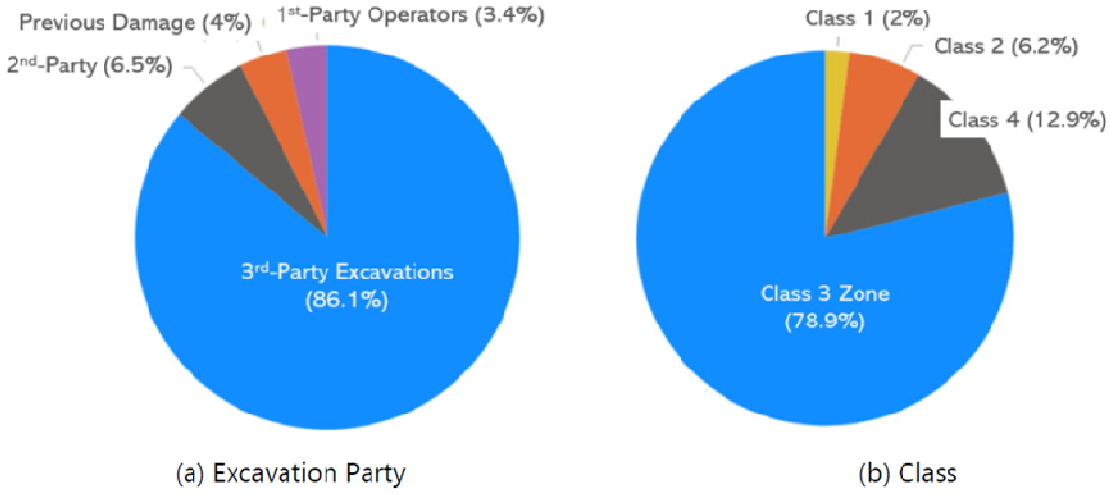
One goal of the project was to bridge the gap to locating technology that can be used in real time during the excavation to increase situational awareness and prevent damage.

Deliverables

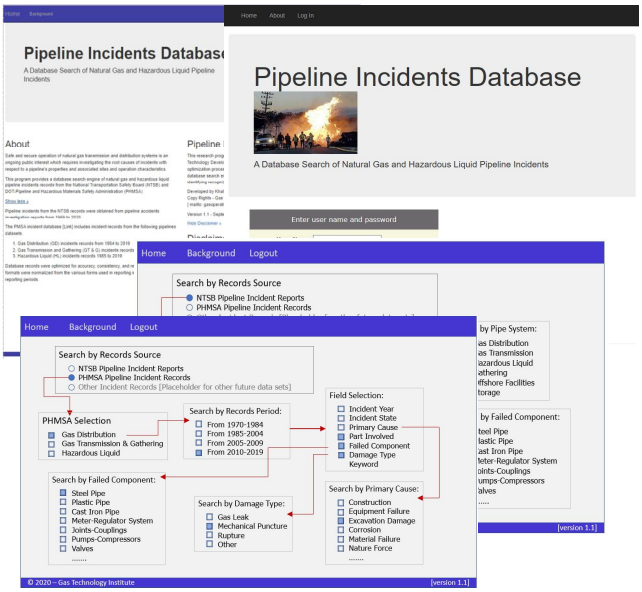
Researchers developed a risk-awareness framework which uses information on underground utilities, site characteristics (such as location, depth, soil properties, and adjacent facilities types) to provide a selection tool of locating equipment and methods in high-risk excavation sites. A situational-awareness framework was also suggested to provide knowledge of the activities at the sites and how communications and actions impact immediate and near-future consequences.

Benefits

This project benefits gas companies and their customers by providing up-to-date information on tools and technologies used to locate utilities and methods and techniques used for safe excavation.



Excavator types and class locations in excavation damage incidents (2010-2019).



Website development.

Technical Concept & Approach

In this project, researchers:

- Identified recent advances in locating, GIS, and excavation technologies that address damage prevention, right-of-way monitoring, and detection of difficult-to-locate systems
- Investigated relevant federal and state requirements and industry best practices
- Selected locating and encroachment-notification equipment to match excavators' specific site properties and operation requirements
- Performed predictive analysis to assist in identifying risk drivers and advancing the assessment of situational awareness of excavation damage, and
- Developed a web-based program and database of excavation-damage incidents and related causes.

Results

Researchers investigated underground locating technologies and provided decision-making tools for reducing the probability of excavation damage to utilities lines.

Excavation damage incidents showed that the main damage root cause in the gas distribution system is *Excavating practice not sufficient* due to the highly congested utilities in this environment. More stringent excavation measures appear to be needed to limit the use of backhoes in clearance zones as they present 46% of poor excavation practices. In gas transmission lines, the main root cause is *Notifications not made*, which is common in excavations in rural and remote areas.

Regression analysis of states' provisions showed few correlations with excavation damage rates in each state. For example, the requirement for back-notification by the locators to one-call systems (positive response of locating) has a strong correlation with a reduction in damage rates in states with such requirements. However, low correlations between other state requirements and damage rates indicate that the requirements are not good predictive indicators of damage rates if they are not accompanied by rigorous enforcement programs.

Most of electromagnetic and ground-penetrating radar locators in the market operate at various multi-frequencies. Many new locators also include various options of integrated data capture, GPS positioning, and graphics, which result in a higher probability of locating lines. However, soil conditions, congested utilities, non-metallic lines and broken tracer wires, and insulated joints can all contribute to difficulties in selecting the appropriate locator type.

The GPR devices provide the most efficient and widely applicable technology for locating non-metallic pipes. While selecting the appropriate GPR frequency is a main part of a successful locating, the user's knowledge of the soil type and experience in the technology are main factors which increase the efficiency and success rate of locating.

A web-based program and database were developed for correlating excavation damage incidents to their relevant site and operating conditions. The program provides the ability to integrate, visualize the output, and statistically evaluate incidents based on their root causes, operation parameters, and site characteristics.

The effects of site characteristics (such as soil type and moisture), pipe attributes (material, size, and depth), and locating practices (such as selecting equipment type and frequency) were also investigated.

A situational awareness framework was developed that compiles the relative information of site characteristics and high-risk features of the gas lines for use by respective stakeholders.

Status

This project is complete. A Final Report was issued in November 2021.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Training Technologies Consortium

In this project, researchers identified new cutting-edge training technologies that can be adopted by utilities for training a new workforce. This effort also included the identification of training service providers and coordination of a workshop where project sponsors evaluated the technologies.

Project Description

As the utility industry prepares for 40%-50% of its workforce to retire over the next few years, utility companies need to reassess their training programs to ensure they will be able to meet the training needs of their new workforce. This workforce, at all levels, will need more than the traditional training class that consists of a classroom discussion, presentation, and hands-on practice in a laboratory under ideal conditions.

Compounding the issue is the fact that company trainers are no longer entering the training department with 20+ years of experience, and field personnel are no longer given the opportunity to train side-by-side with other employees for five years or more before performing work independently themselves.

To bridge this experience gap of trainers and expose trainees to more virtual experiences, researchers are developing new training technologies. The objective of this project was to identify the new cutting-edge training technologies that can be adopted by utilities for training a new workforce. In addition, this effort included the identification of training service providers and coordinating a workshop where project sponsors evaluated the technology and met with industry service providers for each technology.

Deliverables

The deliverables for this project include:

- A Final Report that details the different types of training technologies evaluated and the contacts for each of the service providers. In addition, this report includes details regarding the hardware equipment, software, and any licensing requirements.
- Example training modules created for the training technologies of interest.

Coordination of one Training Technologies Conference for project sponsors and their subject matter experts was performed. This conference included service providers of training technologies.

Benefits

Adopting improved training technologies offers utilities several opportunities and benefits, including:

- Ability to increase learner retention
- Ability to deliver engaging training on demand

"The Training Technologies Consortium has played a critical role in our decision making and the direction of our remote training solutions."

- Tristan Murray
Manager
Training Quality & Innovation
Atmos Energy Corporation

- Ability to deliver training to remote office locations without incurring unnecessary travel and lodging expenses
- Ability to have learners experience hazardous job activities in a safe environment
- Ability to maintain consistency among training sessions
- Access to improved data for conducting training effectiveness reviews
- Ability to bridge the knowledge gap more effectively for newer employees, and
- Ability to introduce new technologies to training departments that may not have the time or opportunity to conduct their own research.

Technical Concept & Approach

Specific tasks in this project involved:

- Identifying and evaluating new training technologies and service providers
- Developing sample training modules, and
- Coordinating Training Technologies Users Conference.

Results

Researchers performed a market survey of commercially available virtual-reality (VR), augmented-reality, and mixed-reality technologies that utilities could potentially adopt as a part of their technical and soft skills training programs. These training technologies were evaluated for their usefulness and potential applications in the natural gas industry. A report summarizes all of the technologies investigated during this project.

When possible, proof of concepts were performed with some of the platforms to demonstrate how they can be utilized by training departments in local distribution companies. The applications of these platforms were also demonstrated to project sponsors during a four-part webinar series.

Through evaluating the various training technologies, the project team created several proof of concepts and are continuing work with a sponsor to support its efforts to build customized 360° 3D video training content.

Outreach to gas industry tool and equipment manufacturers was conducted in an effort to obtain 3D drawings to use in the applications for developing the proof of concepts for this project.

The project team completed a VR proof of concept for a Virtual Classroom and an Operator Qualification evaluation tool. The Virtual Classroom will allow training departments to view and train on any tool, equipment, fitting, or material in a virtual environment with up to 16 people.

Licensing agreements were executed with providers for use of their codeless VR delivery platforms. Customer-generated content can be created and accessed on their platforms.

This webinar series was conducted in March 2021.

The project team continued to support independent project sponsor evaluations for some of the advanced training technologies identified as part of this project. This support included going onsite at an training facility to film various work activities with a 360° 3D high-definition camera and uploading the content to one of the platforms identified and evaluated as part of this project. This video content was then used to create 360° 3D training content that included informational hotspots and assessment type questions.

Researchers visited a training center to capture training content focused on appliance re-light procedures, vehicle pre-trip inspections, loading and operating procedures, and butt-fusion procedures using a hydraulic butt-fusion machine. One of the main goals of this filming was to capture footage from multiple angles by filming with up to three cameras simultaneously.

Status

This project is complete. A Final Report was issued in October 2021.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Pipe Thread Conformance to B1.20.1 Standard – Pipe Supplier Quality Assurance

In this project, researchers investigated pipe thread conformance with the ANSI/ ASME B1.20.1 standard for each major pipe supplier within the industry. The project team created an easy quality-control check and is engaging with pipe suppliers to improve their conformance to the B1.20.1 standard.

Project Description

The natural gas industry expects that the materials a company uses conforms with established standards. When materials do not conform, the potential exists to create unease among customers and regulatory agencies. Also, at a time when methane emissions are a high-profile topic, any extra effort utilities can take to prevent unnecessary methane emissions will be important a safe and environmentally friendly energy solution.

OTD previously sponsored projects related to threaded joint make-up and leak prevention. During OTD project 5.18.w *(Pipe Thread Sealant Performance)*, several pipe manufacturers were identified as providing material not in conformance with the B1.20.1 standard, even though marketing and technical documents referenced being in conformance with this thread standard.

In this project, researchers investigated pipe thread conformance with the B1.20.1 standard for each major pipe supplier within the industry, creating an easy quality-control check, and working with pipe suppliers on improving their conformance to the B1.20.1 standard.

Deliverables

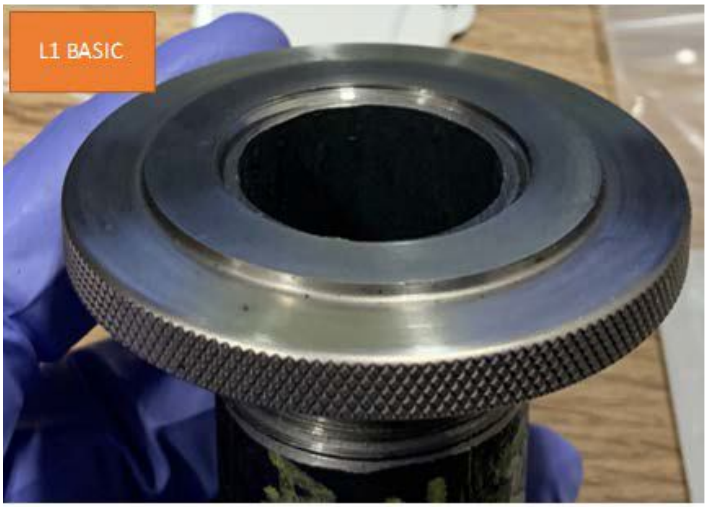
The deliverables for this project include a Final Report that details the conformance findings among the different threaded pipe and fitting manufacturers. In addition, the quality-control corrective actions discussed with any of the pipe and fitting manufacturers will be detailed. Lastly, quality-control steps that can be performed by utility material receivers will be presented.

Benefits

Improved pipe and fitting thread conformance with industry standards may help reduce the total number of premature failures of gas tight joints. These premature threaded joint failures cost utilities significantly to address these nonhazardous nuisance leaks.

Improved fitting conformance will help reduce the following costs and conditions:

- Travel time to leak location
- Meter set disassembly
- Meter set re-assembly



- Appliance relighting
- Decreased customer satisfaction
- Increased employee muscle fatigue and injury, and
- Wasted materials.

Technical Concept & Approach

This project began in 2020 with the identification of known non-conformance issues, sponsor interactions, needs analysis, tasks preparation, and other related activities.

Researchers identified and evaluated the quality-control checks that project sponsors currently perform on pipe and fittings received from suppliers and distributors.

The project team procured pipe and fittings from each of the identified suppliers and distributors. The pipe sizes ranged from ½ inch diameter to four inches in diameter and include stainless steel and black steel. B1.20.1 conformance inspections were conducted on the pipe and fittings. The data from the conformance testing is documented and included in the Final Report.

Results

During a previous OTD project, researchers found that pipe thread sealant performance from various suppliers provided threaded pipe that could not be used since the threading on the pipe did not conform to the ASME B1.20.1 standard that is required for the transportation of natural gas.

Threaded pipe that does not conform to the standard can result in gas leaks and increases the risk of serious incidents. However, it was found that some suppliers marketing and technical documentation identified this material as conforming to the standard.

The project team reviewed existing pipe-thread data and developed a questionnaire to determine a list of pipe fittings and their sizes that are commonly shared by the sponsors for testing. In addition to pipe fittings, some sponsors identified thread-compliance issues in risers, meter bars, and meter sets assemblies.

Multiple vendors were contacted to select a laboratory with expertise and technology to measure threads external and internal with high precision and efficiency. One technology can instantly and concurrently take multiple dimensions and compare to the tolerances of the ASME B1.20.1 standard to provide quantitative results.

A testing laboratory was selected that completed an initial trial inspection with 75 one-inch nipples to determine the sample size. Using the results from the initial thread measurements of 75 samples and considering the material costs of all the pipe fitting types being evaluated as part of this project, a sample size of 110 samples per size/type are being used for measurement.

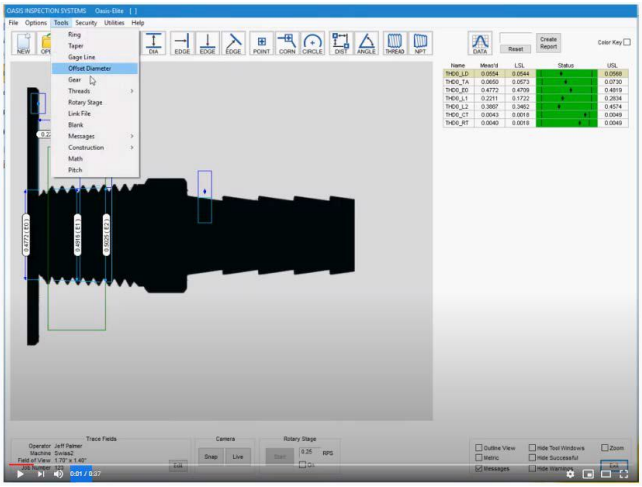


Image of thread with optical comparator.

A method of inspection was finalized for external (non-contact) and internal (mechanical gauging) threads. All products were procured and sent to the laboratory.

All fittings in the test plan were measured. A significant number of the fittings measured were found to be out of tolerance according to the ASME B.1.20.1 standard. Researchers completed a review of the results and validated the findings. The results from the thread measurements are summarized in a report to sponsors.

The project team is following up with vendors to discuss the issues of failed threads and quality-control programs to ensure compliance.

Status

A Final Report is being drafted.

The project team continues contact with pipe manufacturers. Responses from the pipe-fitting manufacturers will be issued as an addendum to the Final Report.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Single-Path Ultrasonic Meter Long-Term Performance Testing and Monitoring

In this project, researchers are installing single-path ultrasonic residential meters on live gas distribution systems and conducting long-term performance and accuracy testing. This data will help support approval from public utility commissions for installing these types of meters.

Project Description

Currently, the natural gas industry does not have independent long-term performance and accuracy data on single-path ultrasonic gas meters. This data is required for utilities to make informed decisions on how and if to use this new meter technology within their gas distribution systems. In addition, some public utility commissions are requiring independent third-party performance testing before allowing the installation of these types of meters.

Researchers finished performing short-term testing on single-path ultrasonic meters through OTD project 5.19.h *Single-Path Ultrasonic Meter Performance Testing*. In this project, a testing rig was built such that single-path ultrasonic residential meters could be installed and tested outside for long-term performance and sustained accuracy over a six-month period.

Deliverables

The deliverables for this project will include a Final Report detailing the outdoor accelerated life testing process as well as the long-term performance and sustained accuracy results of single-path ultrasonic meters.

Benefits

Long-term performance and accuracy data of single-path ultrasonic meters will provide utilities with the necessary information to make business decisions to use this new meter technology. Also, having this data will help support approval from public utility commissions for installing these types of meters.

Ultrasonic meters provide:

Long-term testing rig.

- Improved meter capabilities as compared to diaphragm meters
- Built-in high-flow alarms and temperature sensors, along with integrated shutoff valves, to detect potentially dangerous conditions such as open fuel lines or fires – automatically triggering shut off
- Air detection alerts of potential meter removal, sending an alarm to the utility operations center, improving safety and theft detection, and
- Remotely shutoff service for non-payment, move-outs, line maintenance, or any time the need arises.

Technical Concept & Approach

Project tasks include the construction of a long-term testing rig for the observation and installation of single-path ultrasonic meters during an outdoor accelerated life test. These meters will be monitored for performance and eventually removed for performance testing.

Performance and accuracy testing of the meters installed on the long-term testing rig will be conducted.

Results

During 2020, construction of the outdoor long-term testing rig was completed and the 4,000-hour outdoor accelerated life test on this testing rig began. The rig replicates various meter styles that can be tested at the same time. Researchers decided to use an open flow loop (due to the small volume of air being passed through the system) being supplied by a shop air-line at 90 psi, which would be able to supply the needed flow through the meters without the need for a vacuum pump. The flows will be compared to an in-line reference diaphragm meter.

After three months of testing, all six meters passed monthly sustained accuracy tests. The project team reviewed the procedures for gas-quality testing and formulated two test procedures to test the immunity of meters to contaminants and moisture present in the gas stream.

During the fourth quarter of 2020, the project team also sent a survey to the project sponsors to gather more information regarding their intended usage of the battery-powered smart capabilities as well as how they perform temperature testing on their gas meters.

In 2021, there were multiple issues encountered during the performance testing for three meter manufacturers. Most of the issues were resolved, with the rest being currently investigated by the meter manufacturers. The project team is confident that these issues will be resolved by the meter manufacturers and will only result in a slight delay for completing the remaining testing.

"We feel a safety shut-off valve that can be activated remotely or work autonomously, based on flow and pressure, can be of extreme value to NiSource and the entire gas industry. This feature would significantly mitigate risks and increase safety for our customers and the general public."

- Pat Donnelly
Senior Standards Engineer
NiSource Inc.

Shut-off capability testing and communication testing of meters were initiated. The results of the shut-off leak tightness test indicate good degree of sealing capability of the shut-off valve.

Resistance to water vapor testing on ultrasonic meters was completed and accuracies were not affected, thus reflecting acceptable resistance to water vapor in the gas stream.

Battery evaluation was completed and progress was made in setting up a communication system to evaluate meters which have shut-off and communication features.

Overpressure testing was conducted on a meter. It was found that meter was able to withstand pressure up to 55 psig before a leak was noticed at the flange connection. This test is performed to evaluate the meter's pressure limit and provide information to utilities and is not covered by current meter-testing standards.

There is a continuation proposal being submitted to to extend this project to include the analysis of a residential diaphragm meter. Additionally, testing of the effectiveness of the smart shut-off and communication capabilities of three meters is added to this additional scope.

While the diaphragm meter passed the requirements listed in the standard, the project sponsors and other stakeholders requested for more tests to be performed on these meters in order (to further evaluate the metrology of these meters) as well as testing of additional safety aspects of these smart meters.

Testing is expected to conclude in 2022.

Status

Researchers are performing monthly accuracy tests on the meters as part of the monitoring process of the outdoor accelerated life test.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Barholing and Worker Injuries

Research is being conducted identify the industry's best practices and barhole tooling options for the ability to reduce worker injuries. Researchers are evaluating various available and conceptual barhole tools and methods.

Project Description

When a gas leak is suspected, the utility sends a worker to the site to probe the ground, creating a series of up to 40 or 50 holes. This barholing enables effective location and classification of gas leaks from distribution mains and services. However, barholing was identified by several gas utilities as a major cause of worker injuries.

The barholing technique is simple in that a mechanical tool operating in a pile-driving manner is operated by a single person to penetrate a small hole in the desired location, enabling gas samples to be taken at subsurface levels.

Operators have noted a need for options – both practices and tooling – for barholing related to leak investigations.

There are a variety of methods for making the barhole. One of the most common is through a plunger bar with a slap-hammer design (also called a bar driver). To use the plunger bar, workers must use a downward motion to force the bar into the ground. While the downward motion is awkward, the majority of problems occur when workers must remove the plunger bar from the ground. The motion required is similar to throwing an object straight up with arms slightly bent. The addition of the heavy handle to this motion can cause strains to the back and shoulders.

There are other methods of making the barhole, including using "needle bars" (that are pounded into the ground using a hammer) and using long drills. There are also several methods to remove the rod from the ground, including commercially available bar removers and some experimental or prototype bar removers.

There are also other pieces of equipment that can be used in barholing operations, including pneumatic drills to get through asphalt and concrete.

The objective for this project is to identify and review the industry's best practices and barhole tooling options.

Researchers are evaluating various available and conceptual barhole tooling for the ability to reduce worker injuries.

Deliverables

The deliverables for this project will include barholing guidelines and tooling recommendations based on the ability to reduce worker injury.

Benefits

Barholing is a necessary process during leak investigations. However, the barhole tools used are often manual mechanical devices which can lead to employee injuries. Utilities have a need for better barhole tooling and methods to minimize employee injuries.

Barholing best practices and improved tooling can help reduce worker injuries, reduce costs, and improve worker conditions.

Concept/prototype barhole tooling.

Technical Concept & Approach

The project team is identifying and compiling information on the barholing process, barholing equipment (insertion and removal), work methods, and user input.

In addition, the team is evaluating the best practices and tooling used for barholing. Commercially available and concept tooling will be taken to the field to determine their effectiveness and ability to reduce worker injury. This field study will collect and analyze qualitative feedback from workers using the tools and/or methods. An evaluation of potential adoption success will also be conducted based on worker comments, economic impact, and other factors.

Following evaluations, the project team will develop guidelines, noting the benefits of choosing various types of barholing tooling and/or methods. The guide will describe the various practices and tooling used, the effects (pros and cons) of each, and include information about the potential for any concept tooling identified. If a new product is identified and of interest by the project sponsors, needed technical information will be transferred to a potential product manufacturer.

Results

In 2020, a barhole survey questionnaire was created and distributed to project sponsors. As part of this questionnaire, sponsors were requested to review practices and provide a video of their employees performing the barhole task using the equipment at their company.

"The study highlights the various barholing tools and practices being used in the industry and takes an innovative look at ergonomics. This will benefit the industry by recommending improvements to the tool design, best practices, and identifying ergonomic risks to the body that we can employ to enhance safety."

- Steve Labudzinski
R&D Sr, Specialist
Consolidated Edison Company of New York, Inc.

Based on project sponsor responses to the questionnaire, the following tools are being proposed for an ergonomic analysis:

- A heavy-duty barholing tool
- A rock drill
- A jack plunger with steel rod and replaceable steel tip, and
- A bar-removal tool.

Several meetings were held with a company that specializes in the performance of industrial ergonomic studies to employees performing tasks with various equipment that include computer modeling and studying the forces applied to various areas of the body.

The data provided from all sources for this project were analyzed to create barholing guidelines and recommendations to reduce worker injury while performing the barholing task.

In 2021, redefined protocols for the videos were established and sent to sponsors agreeing to produce videos. Subsequently, several meetings were held with sponsors to review the equipment, videos, and data. Sufficient information and data was received to move forward with performing the required analysis. A final ergonomic assessment report for selected equipment was completed.

Status

The project team continues to obtain ergonomic videos of the equipment in use by field employees from the front, back, and profile.

A Final Report is being reviewed.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Horizontal Directional Drilling Weak Links

Investigators are reviewing the natural gas industry's best practices and evaluating various commercially available weak leaks for trenchless installation of plastic pipe and tubing.

Project Description

New federal regulations for the installation of plastic service lines by trenchless excavation requires that each section of plastic pipe and components that are pulled through the ground must use a "weak link" to ensure the pipeline will not be damaged by any excessive forces during the pulling process.

ASTM F1804-08 *(Standard Practice for Determining Allowable Tensile Load for Polyethylene Gas Piping During Pull-In Installation)* provides a means to determine an allowable tensile load (ATL) value for a polyethylene (PE) gas pipe that is to be installed underground using methods that pull pipe into a trench (cut or plowed), bore hole, casing pipe, or the like. Therefore, weak links must be designed and chosen to fail before the ATL for the pipe being pulled is exceeded.

There are several options for weak links, including breakaway swivels where a color-coded pin(s) is used and designed to break in tension at a specific load.

The objective of this project is to review the industry's best practices and evaluate various commercially available weak leaks for trenchless installation of plastic pipe and tubing.

Deliverables

The deliverables for this project will include weak-link guidelines and contributions to aid in producing a successful directional bore pullback.

Benefits

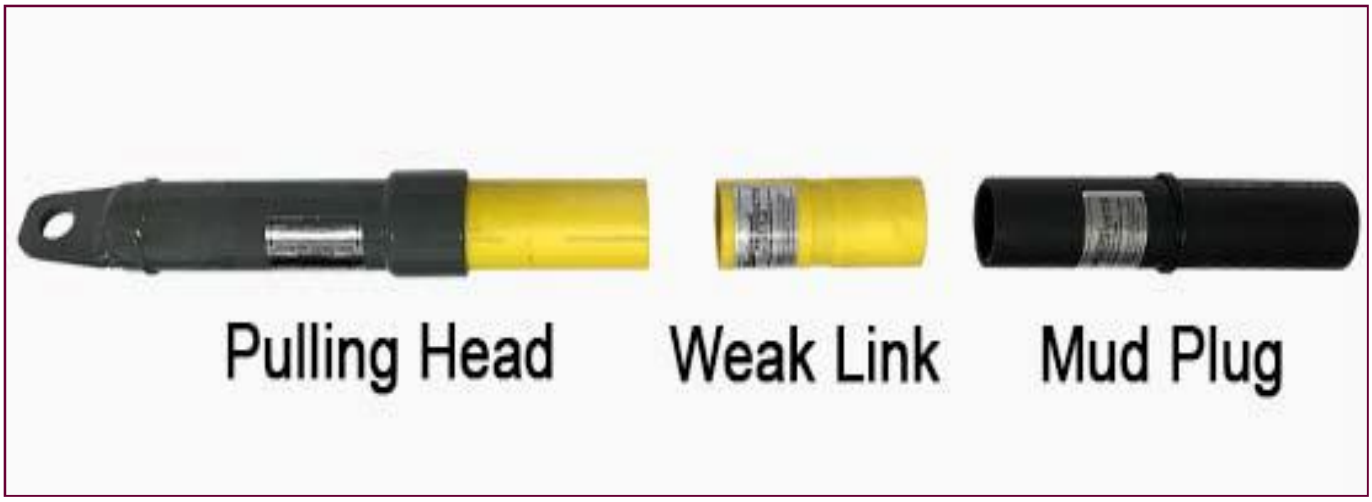
The use of an appropriately-sized PE pipe as a weak link is key in a successful trenchless installation. The weak links are designed to yield before reaching the pipe's standard safe pull strength to protect the pipe from overload – often at a force of approximately 20% less than normal tensile strength of PE pipe.

Providing utilities with accessible information on acceptable types of weak links and best practices will ensure that they are utilizing the appropriate weak link based on the ATL for each standard size of plastic pipe or tubing.

Technical Concept & Approach

In this project, researchers will review acceptable types of weak links available along with performance test results associated with each. In addition to devices, the team will identify and review best practices used for protecting pipe during pull in. The team will reach out to OTD members to identify best practices, procedures, and devices used by each. This information will be used in the development of the guideline document.

The guidelines will help operators address the question of which weak link would be the best option to use. The guide will incorporate the ATL for standard sizes of PE pipe and tubing, break loads of mechanical swivels, and a selection table for using undersized pipe as a weak link.



"These guidelines are key to the proper use of weak links, improving safety and reducing pipeline installation costs associated with horizontal drilling for the trenchless installation of plastic pipe. They will provide a review of the industry's best practices and an evaluation of commercially available products to help gas companies in their daily operations."

- Mark Knight
Associate Professor,
University of Waterloo, Civil and Environmental Engineering
Executive Director,
Centre for Advancement of Trenchless Technologies

Breakaway swivel with color-coded pins.

In addition to a listing of commercially available weak links, the guideline document may include:

- Listing of "homemade" weak links used by the industry
- Advantages and disadvantages of each weak link
- Table of yield strengths for various PE types
- Collection of member procedures and practices, and
- Importance of good practices to minimize the tensile loads on the pipe being pulled in.

Results

During 2020, researchers investigated and met with subject-matter experts on weak links and trenchless technology. Dr. Mark Knight, an Associate Professor in the University of Waterloo's Department of Civil Engineering and Executive Director of the Center for the Advancement of Trenchless Technologies reviewed a questionnaire that was electronically distributed to all the OTD project sponsors for developing a *Weak Link Breakaway Best Practice Guid*e as part of the deliverables for this project.

This guideline document provides a review of available practical information from various manufacturers, utilities, contractors, and researchers into a comprehensive resource. It highlights a set of guidelines that represents the best of what is currently available and its possible limitations.

Based on survey results, about one-fifth of the total respondents indicated that weak links failed in more than 10% of pulls. Additionally, approximately 50% of the total survey respondents were confident that the weak link worked (i.e., performed its function of protecting the pipe from excessive tensile loads).

To date, there is limited data to validate the performance of weak links. Thus, it is possible that the load exerted on the carrier pipe could exceed the PE pipe allowable tensile load before the yield strength is reached.

Weak-link testing showed that a weak link designed to yield at a load of approximately 20% less than the tensile strength of PE pipe can fail at a percentage below or above the 20% yield strength for the same size plastic pipe. Based on this information, it can be deduced that it is possible for a plastic-based weak link not to protect the same size carrier pipe from a load equal to or greater than its ATL.

It is recommended that the development of data logging systems should be investigated. The use of data loggers will help to monitor the pull load at any given time during the pipeline installation.

It should be noted that smaller-diameter and thinner-walled plastic pipes can be used; however, care must be exercised to ensure that the weak link is strong enough to resist the anticipated installation load.

Status

This project is complete. A Final Report was issued in July 2021.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Removing Water-Vapor Impurities to Improve Gas Quality in a Distribution Pipeline

The objective of this project is to design and fabricate an in-line desiccating system that can remove water vapor in natural gas distribution assets. At the conclusion of the project, an in-line desiccating assembly will be provided to project sponsors.

Project Description

Concern with water buildup accumulating in distribution pipelines from unknown sources has become a common issue in the natural gas industry. Understanding supplemental in-line cleanup technologies could provide useful turnkey solutions to remove other impurities.

Due to system pressure drops, aging infrastructure, and new sources of renewable natural gas entering the system, water vapor has a variety of means to by-pass traditional cleanup processes and condense in a distribution asset. With increasing avenues for water infiltration, supplemental cleanup with a modular process that does not require energy input could provide a straightforward in-line solution. Left untreated, the accumulation of water poses a hazard to pipeline integrity and component operability, and can cause customer outages. These problems are exacerbated in freezing conditions.

To address the accumulation of water condensation, this concept is to develop an operationally flexible in-line desiccant assembly. This desiccating system is designed for in-line placement upstream of components where there is a high risk of impacts such as freeze-ups, process disruptions, and component malfunction.

The goals of the project are to design, fabricate, and test a desiccating system that could be applicable in natural gas distribution systems.

Deliverables

At the conclusion of this project, results of tests with a selection of desiccant materials will be provided, along with information about the design of the desiccant assembly. The development of a manual for in-house fabrication or identification of a commercializing partner can be explored with project sponsors.

Water-vapor removal test rig.

Benefits

By better understanding in-line cleanup concepts, recommendations can be formulated for modification of existing equipment and development of more advanced desiccation systems. If proven effective, in-line assemblies can help prevent equipment damage and operational issues that threaten safe and reliable operation.

Technical Concept & Approach

The need for a water-vapor removal system is primarily focused on residential customers. Feedback suggested that the lifetime of the system should be on the order of months. The sponsors indicated that the water-vapor removal system should require little to no maintenance, but were open to one or two "change-outs" of desiccant material in winter months if this approach proves effective.

Researchers identified and evaluated commercially available desiccants and potential designs for in-line deployment.

Desiccants for testing were selected and the test apparatus was fabricated. Testing is now in progress, subjecting the desiccants to conditions of varied moisture content.

Results

There are effectively five categories of desiccant materials: molecular sieves, silica gels, clays, calcium oxide, and calcium sulfate. Each desiccant type offers variable performance properties that will be explored throughout testing. The three most important properties will be adsorption capacity, adsorption rate, and resistance to odorant fade. Through testing, these values will determine the desiccant composition and sizing requirements of the desiccant housing system.

In 2021, researchers screened desiccants for resistance to odorant fade prior to testing. Odorant fade is evaluated by measuring odorant concentration upstream and downstream of the desiccant bed. The experimental apparatus was designed to evaluate the performance of the desiccants at flow rates of up to and beyond 250 standard cubic feet per hour. The full testing assembly was constructed and placed in a walk-in environmental control chamber in accordance with testing parameters.

Tests are conducted at low pressure to emulate conditions in a distribution system, with flow control and recording of the total volume of flow being passed through the system. Desiccant performance is evaluated in terms of changes in moisture content across the desiccant bed, correlated with relative humidity and temperature data.

Sample desiccants are loaded in the housing chamber with inlet gas directed to the bottom of the housing and forced upwards so that the gas is in uniform contact with the desiccant bed. Outlet gas exits the housing assembly at the top. Changes in moisture concentration are measured at inlet and outlet sampling ports.

To begin, the concentration of the odorant Tert-butyl Mercaptan (TBM) present in the supply gas was measured at the apparatus inlet and outlet without any desiccants in the housing assembly. This was to assure that factors associated with the system configuration were not contributing to odorant fade. After verifying inlet and outlet concentration of odorant in the natural gas are unchanged, odorant fade resistance screening commenced. Odorant concentrations at the inlet and outlet gas stream are recorded and compared among the various candidate desiccants tested.

Status

Odorant-fade resistance screening indicated a propensity for desiccants to adsorb and diminish odorant concentrations in the gas stream. Two candidate desiccant materials were selected for further screening. Testing is ongoing.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Smart Shutoff Technology for Commercial and Residential Buildings

A project team is providing utilities with "smart solutions" to implement smart safety shutoff devices and sensors which includes a pilot demonstration for a natural gas smart shutoff system for residential and commercial customers. Initial activities include conducting market research to determine gas customer preferences with smart shutoff safety systems.

Project Description

Currently, the natural gas industry infrastructure lacks enhanced smart safety features that can detect and terminate gas flow in response to a hazardous incident, such as a gas leak inside a residential or commercial structure. There are commercially available standalone devices such as excess flow valves and natural gas leak detectors; however, these devices do not possess the communication ability to automate a safety response among emergency personnel, gas customers, gas shutoff, and the local gas distribution company.

A natural gas smart safety shutoff system would provide an additional layer of protection for customer life and property by detecting hazardous conditions, providing appropriate alerts, and having features that can automatically take preventative actions such as stopping the flow of gas into a structure.

This co-funded project with the California Energy Commission will provide the natural gas industry with the necessary hardware and software components that comprise a full solution smart safety shutoff system for use in residential and commercial structures.

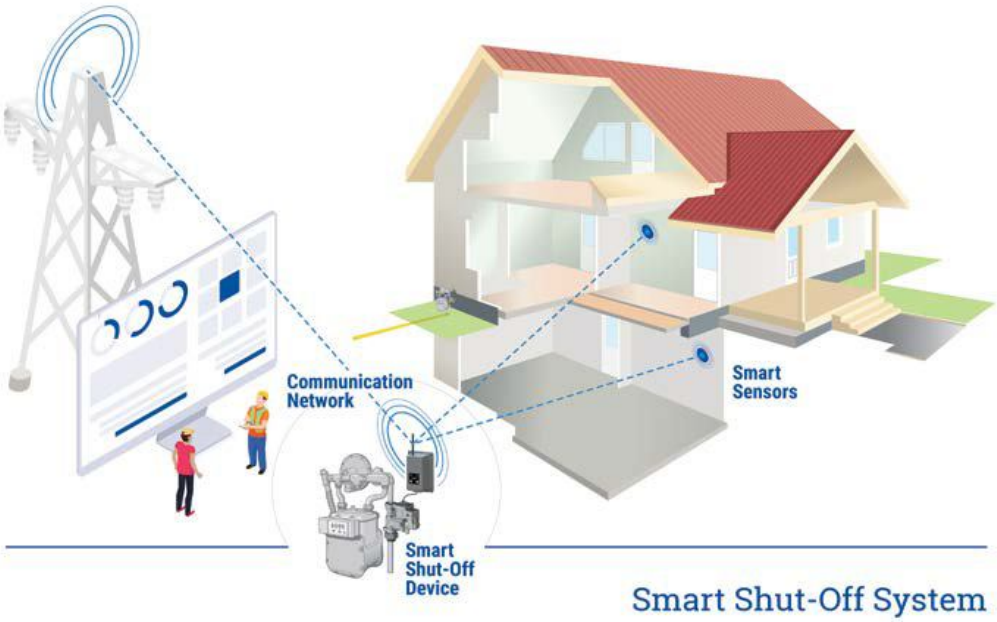
The system will consist of the four basic components:

1. **Smart Sensors:** Devices that can be placed inside or outside a structure that "sense" the surroundings for abnormal conditions. When these sensors find an abnormal condition, the sensor will send out an alert that can be received by other smart devices, including an automatic gas smart valve that will shut off and stop the flow of gas into a structure or appliance.

2. **Smart Shutoff Valve:** An automatic valve that is connected to smart sensors that will stop the flow of gas into a structure (or appliance) if signaled by a smart sensor.

3. **Communication Network:** Communication platforms that connects the operator with the smart sensors and smart shutoff valves.

4. **User Interface/Software:** Status of the sensors and valve will be viewed by the smart valve operator and possibly by the gas consumer. The smart valve operator will have the ability to actuate the valve, which stops the flow of gas, in the event of an emergency or request by the end user.



The specific objectives of this project are to:

- Determine natural gas customer (i.e., the ratepayer) preferences with smart shutoff safety systems
- Identify emerging natural gas concentration and temperature safety sensors and network communication strategies
- Integrate and test promising safety sensors and communication protocols to validate performance of the natural gas smart shutoff system, and
- Perform a pilot demonstration of a gas smart shutoff system for a residential and commercial customer.

Deliverables

The initial deliverable is the final Customer Research Plan, which includes the progression of the multi-phased effort. The purpose of performing customer research is to gain insight as to the best strategies to implement a natural gas smart shutoff system with customer acceptance. The ultimate deliverable is to demonstrate a smart safety shutoff system in the field.

Benefits

Conducting customer research and identifying and validating the performance and safety features of such a system would help establish a natural gas smart shutoff technology ecosystem and aid in the adoption of smart shutoff technology. The implication of this would be additional layers of protection to hazardous situations and streamlined safety responses.

The benefits of such a system are decreased emissions, prevention of property damage and personal injury in the event of a hazard, and a decrease in incidents caused by natural gas leaks in distribution systems. However, two significant challenges currently prevent the adoption of this technology and require additional research. The first is that various smart sensors, safety valves, and network communication technologies exist, but have not been assembled in such a way to provide an effective natural gas smart safety shutoff solution. The second is that questions remain regarding the most important features in a smart shutoff technology and the best strategy to deploy this technology that meets the needs of both the natural gas customer (ratepayer) and local gas distribution company.

Technical Concept & Approach

In the current Phase 2, information collected from Phase 1 is being used to improve the line of questioning for two surveys targeting residential and commercial natural gas customers. These surveys will collect data on customer preferences pertaining to of this technology to help build the overall strategy for improved adoption.

These efforts are followed by the identification, evaluation, and demonstration of smart shutoff valves, sensors, and combined systems.

Results

Initial activities included development of the Customer Research Plan, which consists of a two-phase interviewing process for gas utilities and natural gas customers on the thoughts and aspects of a natural gas smart safety shutoff system.

In 2021, customer research results were presented and discussed in a June 2021 meeting and the results were then distributed to the project stakeholders. The customer research analysis had provided a variety of high-level conclusions for the smart shutoff system, including information of system appeal, sensors, shutoff, notification, hacking/privacy, communications networks, ownership models, bundling, and cost.

A Hardware Specifications and Design Report and a Specifications and Design Report were developed.

The project team created a functioning mock-up demonstration of the Natural Gas Smart Safety Shutoff System and has successfully tested the system multiple times using residential methane detectors (RMDs). Researchers successfully validated the hardware and software for system.

The project team is working with a collaboration to understand the challenges of implementing a LPWAN at a gas utility. The collaboration between ecosystem partners has been successful thus far and is indicative of the open-standards approach to delivering gas safety to ratepayers. The purpose of the project aims to provide California gas utilities with smart solutions to implement smart safety shutoff devices and sensors.

Status

Researchers are completing a variety of related reports for sponsors. Testing is being conducted on heat/fire smart sensors for the safety system. Demonstrations are planned.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Product Performance and Validation Program

For this project, researchers are creating a program to validate gas-industry product performances to confirm that manufacturers still produce high-quality material meeting customer and industry requirements. The program compares performances of similar products from various suppliers to help in making informed decisions for their continued usage.

Project Description

Requirements to validate product performances at the design level are well defined in various industry standards. In the natural gas industry, the requirements outline comprehensive testing protocols to evaluate product design or re-design, material, and production processes.

In the commercial manufacturing environment, production processes (equipment, technology, etc.) throughout the lifecycle of a product are constantly changing. Industry standards – with some exception – have no requirements to address these types of changes.

There are a few examples in the natural gas industry of standards that require ongoing product testing. For example, ASTM D2513 requires semi-annual extrusion process qualification of a PE pipe, and CEN 1555-7 (European standard) requires ongoing process verification testing for electrofusion fittings to confirm that tests originally performed on products or joints/ assemblies at the design level continue to be valid and the process continues to be capable of producing products that conform to the requirements given in the relevant standards and customer specifications. However, based on observations made during years of quality auditing, the process of ongoing product validation has not been adopted and implemented by most manufacturers due to a lack of industry requirements and increased pressure to improve efficiency and reduce costs. Therefore, there is a need for an ongoing standardized product-testing program that will complement current quality auditing and material-supplier quality-assurance programs.

This program will compare performances of similar products from various suppliers to help in making informed decisions for their continued usage.

This program also has the ability to assist in the approval process for new product lines or components.

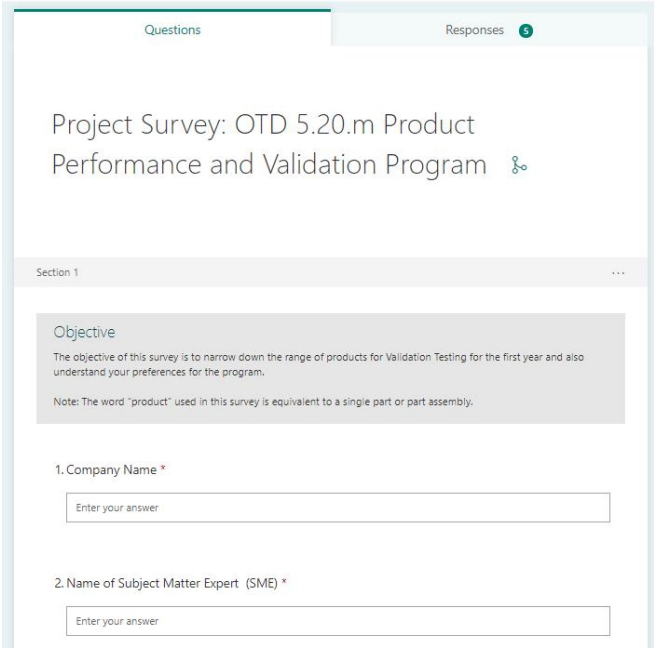
Deliverables

The deliverables for this program will be individual reports for each set of tests by product type and an annual final summary report of the comparison of product performances

Benefits

The goals of this program are to:

- Create efficiencies and cost savings by consolidating the validation and testing of products shared by the sponsors
- Assess if products meet the requirements of the industry standards and customers
- Provide information on product performance to make more informed choices
- Provide information that can be used during an annual evaluation of suppliers



- Provide information for the approval of a new supplier/product, and
- Allow sponsors to enhance their internal quality-management systems.

Technical Concept & Approach

This program creates an ongoing testing-validation process for products and materials used in the natural gas distribution industry. The product selection is based on a decision tree that helps to identify the pertinent candidates, including such considerations as:

- Criticality
- Product type
- Suppliers' site
- Size
- Product configuration
- Sponsor's infrastructure, and
- Working conditions.

The test methods employed are based on the requirements of relevant industry standards and sponsor requirements. Some testing efforts may be enhanced with additional test methods based on the experience and knowledge of subject matter experts in the field.

Activities include sample collection/procurement, sample preparation, and testing. The number of samples to be prepared will be determined based on testing and evaluation needs discussed and finalized with project sponsors.

The first year of the program will include testing of four sets of tests of electrofusion fittings, where one set is comprised of 30-36 samples of the same product size/ manufacturer/product type/product material fused to the same pipe type to undergo a variety of tests, including:

- Dimensional Analysis
- Quick Burst
- Sustained Pressure
- Peel, and
- Tensile or impact.

The testing plan includes the testing requirements defined in ASTM F1055-16a Standard Specification for Electrofusion Type Polyethylene Fittings for Outside Diameter Controlled Polyethylene and Crosslinked Polyethylene Pipe and Tubing. In addition to the industry-required tests, peel de-cohesion test was added for couplings and a de-cohesion test for the tapping tees following the requirements of ISO 13954 and ISO 13956, respectfully.

Results

The project team submitted a survey to project sponsors in October 2020. The survey asked a series of questions to narrow the range of products for testing.

In 2021, the team created a comprehensive test matrix for recording the fusion parameters for 222 fused assemblies, in addition to recording the test results for all the prepared fused assemblies.

The research team completed dimensional measurements of pipe samples designated for quick-burst and sustained hydrostatic pressure testing (96 segments in total). Resistance measurements were completed on all fittings (222 fittings in total). A total of 135 fusions were made.

Status

The following activities are scheduled for execution:

- Preparation of the remaining 95 fusion joints
- Initiation of the testing and analysis of the prepared fusion joint assemblies
- Preparation of 12 fused assemblies for elevated temperature hydrostatic pressure testing and test them at 176°F, 580 psi hoop stress for 1,000 hours
- Perform falling weight impact testing of 24 tapping tees
- Perform de-cohesion testing of 24 tapping tees, and
- Perform tensile pull testing of 24 couplings.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Pipeline Safety Management System Training Development

For this project, a research team is developing Pipeline Safety Management System training content to help educate and inform stakeholders. Investigators are collecting information on the needs and requirements of the project sponsors to develop training content that can be delivered and used by the gas industry in general.

Project Description

The natural gas distribution industry is at a critical point where 40%-50% of the workforce is expected to retire over the next five years. Because of this large turnover rate, the goal of zero pipeline incidents will become even more difficult to achieve without the adoption of a Pipeline Safety Management System (PSMS) to address the knowledge and experience gap of the new workforce entering the organization.

In addition, there are recommendations at the federal level that may require all utilities to have a structured PSMS implemented in the near future. Consequently, it is important that a well-thought-out communication and training program is developed.

The objective of this project is develop PSMS training content (e.g., videos, handouts, etc.) to help educate and inform stakeholders (e.g., leadership, field personnel, contractors, etc.) on their role in the plan. This will be accomplished by gathering the needs and requirements of the project sponsors and then develop training content that can be delivered and used by all project sponsors and the industry in general.

Deliverables

The deliverables from this project will include:

- A Final Report detailing the training content developed and the process followed for developing the training.
- Access to training material, including
  - Training needs assessment from project sponsor subject matter experts

PSMS modules.

- An instructor guide for delivering developed training content
- Handouts for new training content
- Computer-based training modules, and
- Access to a delivery platform.

Benefits

Development of common training content will provide:

- Consistent training related to PSMS, which will help reduce additional scrutiny at the state commission level for needing customized training
- A more knowledgeable industry on the subject of PSMS as a whole, beyond those organizations with only dedicated PSMS staff
- Reduced training-development expenses as a result of pooling funds, and
- Improved training content as a result of identifying PSMS training needs and requirements.

Technical Concept & Approach

Ten elements of a PSMS will be used as a starting point for identifying and organizing the training curriculum. In addition, the different stakeholder audiences (e.g., leadership, field staff, contractors, etc.) will be identified.

The project team will conduct a pilot test of the developed PSMS training content with project sponsors. The stakeholders of each training module will have an opportunity to complete and evaluate the training in advance of an organizational-wide release. The pilot test feedback will then be used for making any updates to the training content and/or delivery method(s).

Results

In 2021, the project team began the project creating a working group made up of subject matter experts from the project sponsors. This group meets semi-monthly to provide input on training needs, content development, and training delivery methods

A survey was also developed to evaluate the PSMS training needs of project sponsors.

Outreach efforts to were conducted with third-party training vendors to discuss the file type needed to deliver the e-learning PSMS training modules that project sponsors can use in content delivery platforms. With a training development consulting partner, the project team is creating training module storyboards.

The PSMS Working Group used the survey to identify the stakeholder groups and training topics for which training content will be developed:

- Senior Management
- Mid-Level Management
- Frontline Supervisors
- Engineers
- Company Field Employees, and
- Company Contractors.

Development of all seven modules were developed:

1. Introduction to API RP 1173
2. Essential Elements of API RP 1173
3. PSMS Journey
4. Contractor Engagement (Internal)
5. Contractor Engagement (External)
6. Importance of Culture
7. Leadership Commitment.

Status

The project team plans to publish all seven modules to OTD project sponsor learning management systems.

A Final Report is being drafted.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Meter Removal Tool

Efforts are under way to provide a market-ready meter removal tool that can safely, quickly, and effectively loosen seized meter swivel collars. This tool will improve employee and customer safety and reduce time required to repair customer piping leaks created during routine meter changes and removals.

Project Description

There is an estimated 66.7 million residential natural gas meters in the United States that require periodic "aged" and "sample" meter changes during its life cycle. Based on input from utilities, it is estimated that 20% of the outdoor meters may have seized meter swivel collars that requires excessive force to loosen. This amounts to a significant number of opportunities for currently installed residential meter sets to cause an employee injury or a downstream gas leak on customer piping due to excessive pipe-wrenching activities.

The goal of this project is to provide a market-ready meter removal tool that can safely, quickly, and effectively loosen seized meter swivel collars.

This project represents the second phase of the Sustaining Membership Program's *Compact Meter Removal Tool* effort. During Phase 1, a working prototype was designed, developed, tested, and enhanced. Currently, researchers are testing the pre-production version of this prototype tool.

Enhancements include:

- Eliminating the need for different-sized wrenches for the various meter swivel collars. The new design includes an adjustable pipe wrench.
- Redesigning of the vise grip, the adjustment nut, the location of the spring mechanism, and the locking position of the handle.
- Increasing the travel distance of the push rod.
- Increasing the strength of the adjustable pipe wrench.
- Redesigning the worm gear to reduce the total number of revolutions required to advance the push rod completely.
- Designing a user-friendly ratchet handle.

This project involves collaboration with an industry tool manufacturer to enhance the design of the meter removal tool prototype and ultimately bring it to market for the industry.

Deliverables

The deliverables for this project include:

- A field-tested product produced by a third-party tool manufacturer prepared to commercialize the tool
- Generation of a commercialization agreement with a third-party manufacturer and distributor, and
- A Final Report describing the improvements of the design and testing results of the final product.

Benefits

Having a meter removal tool to assist with un-seizing meter swivel collars will help prevent soft-tissue injuries to field technicians and reduce the potential for

Field test prototype.

creating downstream gas leaks on customer piping due to the excessive stress and strain created from pipe-wrenching activities required to un-seize these fittings. This tool will improve employee and customer safety along with reducing time required to repair customer piping leaks created by during routine meter changes and removals.

Technical Concept & Approach

Project tasks include:

- **Design Refinement of Tool**

  Activities in this task includes working with a tool manufacturer to refine the design of the meter removal tool such that it is stronger, more effective, and can be easily fabricated by the tool manufacturer.

- **Fabrication of Final Tool Design**

  The manufacturer will fabricate the final meter removal tool with oversight by the project team to ensure tool requirements are met. Engineering design services for enhancements and tooling expenses for mass production of the tool will be provided by the manufacturer at little or no cost for the opportunity to commercialize the tool.

- **Laboratory and Field Testing of the Tool**

  This task includes testing the fabricated the meter removal tool by the manufacturer and testing it on meter sets in the field.

- **Commercialization**

  Efforts will be made to bring this product to market; including but not limited to, working on protecting intellectual property and seeking patents, identifying and working with potential distributors, and efforts to secure licensing agreements.

Results

In 2021, the project team conducted a kick-off call with project sponsors, identifying the project team, meeting with the tooling manufacturer to review the commercialization process for this phase, and initiating a request for prototype #4 samples of the tool to be delivered to project sponsors.

The design enhancements for prototype #4 include:

1. The adjustable clamp (e.g., vise grip) teeth were redesigned and now have the same design as a pipe wrench. This new design will improve the grip of the meter swivel and reduce clamp slippage when working on seized meter collars.

2. The Allen bolts connecting the two halves of the adjustable nut for the adjustable clamp (e.g., vise grip) were upgraded to a higher grade of steel and have increased in length to increase the strength of the adjustable nut.

3. The storage case was redesigned to allow for easy storing when putting the tool back into the case.

Status

Testing is ongoing. Researchers are coordinated semi-monthly update meetings to share project sponsor feedback on design enhancements. An electronic survey is being created for collecting project-sponsor feedback on field-testing results.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Damage-Prevention Training Program

Investigators are developing a computer-generated virtual reality training module and 360° 3D video modules for damage-prevention activities. Training content will be made accessible on a content-delivery platform that allows stakeholders to access the training.

Project Description

Damage to underground facilities continues to be a concern to the natural gas industry. In addition to the inconvenience of service outages and the expense for time and material required to make repairs, these damages create risk to responding employees, the general public, and property.

A related concern is the increased turnover of personnel within utilities, contractor locator companies, excavation companies, and other stakeholders. This increased turnover is considered to be a contributing factor to facility damages.

The goal of this project is to create engaging training that is easily accessible to all locating and excavation stakeholders in an effort to achieve zero excavation damages to underground facilities.

OTD completed development and deployment of a virtual reality (VR) training module for facility locating and marking as part of project 5.18.t. *Virtual Reality Training Library Development.* In this new project, the goal is to develop one computer-generated VR training module and up to six 360° 3D high-definition video VR training modules for damage-prevention activities. Training content will be made accessible on a content-delivery platform that allows utilities, contractors, and other stakeholders to access the training. In addition, training records will be saved and accessible for audit purposes.

Deliverables

The deliverables for this project include:

- A Final Report detailing the training content developed and the process followed for developing the training

Properly marked services.

Marking newly installed services.

- Access to training material developed, including: training needs assessments subject-matter experts; an instructor guide for delivering developed training content; and handouts for new training content, and
- Trial access to the delivery platform.

Benefits

Improved and more accessible damage-prevention training will help reduce utility infrastructure damage, employee injuries, customer injuries, customer property damage, liability claims, and service outages.

In addition, by using advanced technologies such as VR for training-content delivery, the training is more engaging and is retained by the trainee at a higher rate than traditional classroom or computer-based training.

This type of training can also be delivered on-demand to external stakeholders without requiring access to a learning-management system.

Technical Concept & Approach

The project team will initially identify the training needs and requirements of each project sponsor. In addition, researchers will identify the best technology for delivery of each training module developed. Guidance from the Common Ground Alliance, National Utility Locating Contractors Association, state one-call centers, locating contractors, excavators, and project sponsors will provide input for development of this training content.

A pilot test of the developed damage-prevention training content will be conducted with project sponsors. The stakeholders of each training module will have an opportunity to complete and evaluate the training in advance of an organizational wide release. The pilot test feedback will then be used for making any updates to the training content and/or delivery method(s).

Results

Project activities in 2021 included performing project scoping activities, establishing a project sponsor working group to provide direction on training content for development, and the identification of training content.

Trainees will have to "recognize and react" to a variety of scenarios (e.g., excavation, horizontal directional drilling, homeowner activities, site inspections, and locate markings).

The project team identified six 360° 3D VR training modules for development. These modules will allow trainees to interact and navigate environments related to damage-prevention activities, such as pre-excavation inspection (e.g., maps, records, and inspection of the surrounding area for natural gas facilities.

Status

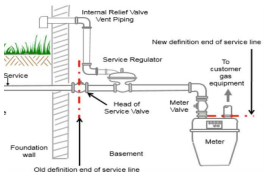
The project team and the project sponsor working group continues to identify learning objectives for each training module.

Development activities were initiated on each training module. This will include conducting field visits to film 360° 3D high-definition video content.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Procedures for Retrofitting Indoor Gas Service Regulators



Researchers are developing best practices and guidelines for the retrofitting of inside gas service regulators and associated piping to maintain the same level of safety as a regulator installed outside. This project will provide the actions required to investigate, rehabilitate, and retrofit indoor gas regulators and piping systems.

Project Description

Incidents caused by regulator over-pressurization, improper installation, improper maintenance, and corrosion of vent lines of indoor regulators and/or meter sets are increasing in concern in the natural gas industry.

The National Transportation Safety Board recommended to the U.S. Department of Transportation's Pipeline and Hazardous Materials Safety Administration (PHMSA) that existing interior service regulators be relocated outside whenever the gas service line, meter, or regulator is replaced. However, there are certain challenges in relocating indoor regulators where no outside space for a gas service regulator exists or municipalities in certain business districts restrict the outside piping. In these situations, when a regulator must be installed inside, equipment and devices may be used to manage vented natural gas and provide warning and emergency shutoff if gas accumulates indoors.

This project involves the development of best practices and guidelines for the inspection and retrofitting of inside gas service regulators and associated piping so that the inside regulator will provide an equivalent level of safety as compared to gas regulators located outside of the structure.

Researchers are evaluating existing industry standards and practices for the installation and maintenance of inside regulators and piping systems and will recommend technologies based on a variety of issues.

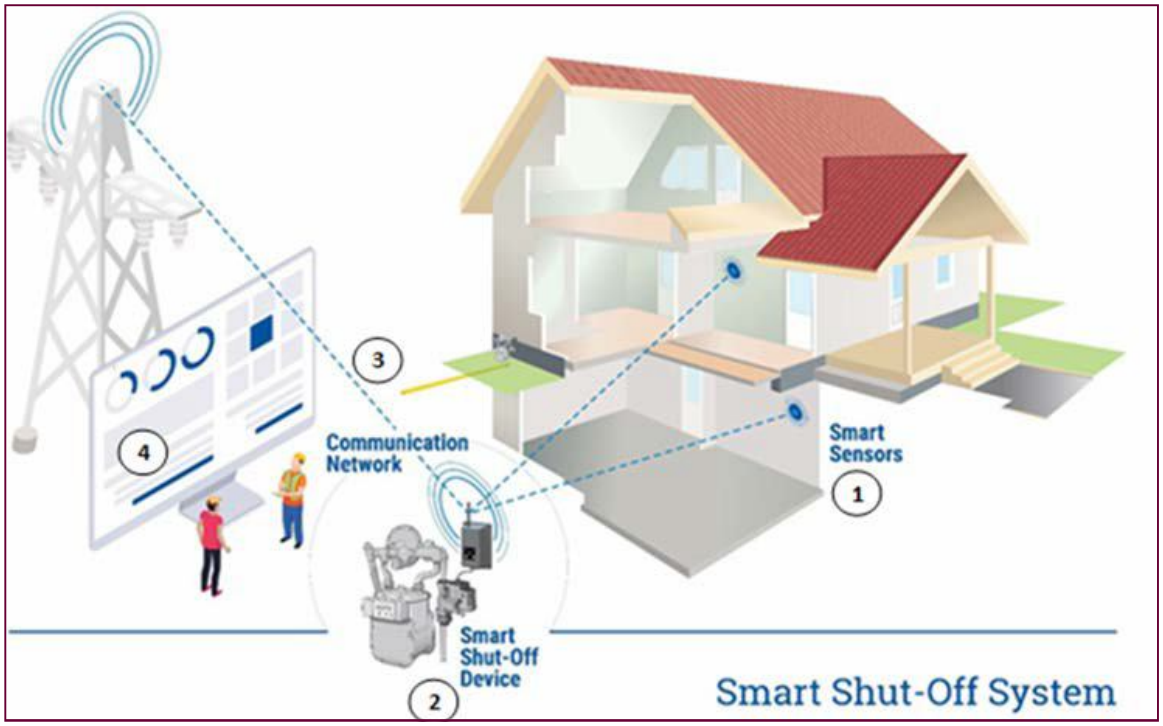
The project is co-funded by the PHMSA.

Various projects on testing and evaluating new technologies are presented in reports.

Deliverables

Key deliverables for this project include:

- An evaluation of retrofitting and rehabilitation Retrofitting practices
- A Final Report, and



- A PHMSA webinar to present the research results.

Benefits

Safety risks and maintenance costs increase significantly when gas service regulators and associated higher-pressure piping are installed inside since vented gas from regulators and leaks from the piping systems may accumulate in a confined space. This risk increases when customers make improvements to the inside of their premises by building or modifying the structure around the regulators and potentially altering the equipment's function. However, natural gas supply to many residential, multi-residential, and commercial dwellings necessitates the installation of indoor regulators (many in meter rooms) where outside installations are not feasible or practical.

This project will provide the actions required to investigate, rehabilitate, and retrofit indoor gas regulators and piping systems.

Technical Concept & Approach

Project tasks include:

- **Review of Current Practices and Technologies**

  Researchers will investigate and collaborate with subject-matter experts (SMEs) to compile existing technologies and practices for: inside piping and regulator installation and inspection, procedures for inside piping and regulator records retention, and products currently in use or piloting to retrofit inside regulators.

- **Inspection and Retrofitting of Indoor Regulators**

  There are new technologies that can potentially be used to retrofit new or existing inside regulators and stop the flow of gas in the event of a regulator failure. This includes smart shutoff valves that have the ability to incorporate methane sensors for improved safety. These technologies will be identified and reviewed based on their ability to be used to retrofit inside regulators to increase safety.

- **Inspection and Rehabilitation of Regulator Piping Systems**

  Besides venting, several other factors increase the risk of potential leaks of inside meters and associated piping. This task will investigate potential leaks caused by piping systems, other than the regulators' venting events. Factors include pipe age, installation procedure, inspection procedure, piping support and placement, condition of the coating, and relative humidity.

- **Best Practice Guidelines and Recommendations**

  The project team will develop best-practice guidelines for the installation, inspection, and record capture for inside regulators with the TAP and industry SMEs.

Results

In 2021, the project team completed a compilation of current practices and technologies for inside piping and regulator installation and inspection. Several technologies, including smart shutoff valves and methane detection sensors, were evaluated based on test results from several research and testing programs.

The use of methane-detection sensors inside regulator rooms could potentially create an audible alert to customers in the event of a gas leak inside the structure. In addition, smart technology can connect to existing communication networks to notify the gas utility in the event of the detection of a gas leak and remotely shut off the flow of gas.

A total of 21 brands of remote methane detectors were tested. At least three devices from each manufacturer were tested.

Remote methane sensing devices were first tested with methane gas, followed by propane then the household products and chemicals.

It was noted that there have been various improvements in regulator designs over the past several years which incorporate features such as slam shuts for over- and under-pressure conditions, vent-limiter devices, and excess flow shutoffs to improve regulator safety as compared to earlier models. Many of these regulators have a small footprint and are easier to install outside because they have no clearance requirements.

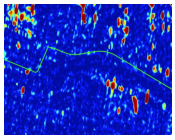
Status

An investigation of available technologies continues. These technologies may include low-emission regulators and smart shutoff valves which incorporate methane sensors to improved safety. These technologies will be identified and reviewed based on their ability to be used to retrofit inside regulators.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Evaluation of the CoSMiC Eye Satellite-Based Pipeline Right-of-Way Monitoring System



Researchers are conducting a technical review and evaluation of the CoSMiC Eye satellite-based pipeline monitoring system. CoSMiC Eye completed successful field trials in Germany and field trials are being prepared for France and Italy. This project will evaluate its use in North America and the potential benefits it offers.

Project Description

The encroachment of new buildings, roads, and other construction activities and the mechanical damage incurred from unauthorized third-party activities are leading concerns of natural gas pipeline operators. The damage and stress placed on a buried pipeline from ground movement and subsidence is also a great concern.

Pipeline patrol is a federally required activity that is essential to ensuring the safety and integrity of gas transmission facilities from external threats and, in so doing, helps to enhance public safety. The patrol identifies and reports on a variety of observations, including abnormal operating conditions, potential commercial threats to pipeline integrity (e.g., digging, farm-field ripping, boring, blasting, etc.), new construction activity and large ground movement caused by natural events. This indicates the need for effective strategies to monitor for these pipeline threats over extensive sections of pipeline right-of-ways (ROW).

Researchers found that the CoSMiC Eye satellite-based pipeline monitoring system – which uses both radar and optical imagery – has the potential to detect potential threats in a pipeline ROW. Although satellite-based pipeline monitoring is not new, recent advances in several fields (including radar, optical satellite imaging, artificial intelligence, and data analysis algorithms) enabled the development of CosMiC Eye's capabilities. In operation, the system analyzes a time-series of radar images to detect activities on and near a pipeline ROW. CoSMiC Eye collects, processes, and analyzes radar data from the European Space Agency Sentinel-1 satellite constellation. For this, it uses proprietary algorithms in a fully automated fashion with little operator involvement. In each subsequent pass of a Sentinel-1 satellite, a new radar image is obtained and analyzed, together with a number of prior radar images for the same location, to identify any changes in pipeline ROW conditions. These include the presence of construction equipment, road work, structures, buildings, etc.

For locations where activity is detected that could potentially damage the pipeline, data from optical satellites is acquired. This enables the customer to analyze the location from the office.

For changes deemed relevant by the CoSMiC Eye system, an alert is issued to the pipeline operator. This alert is in the form of a geo-reference object that can be displayed as a marker on a map at the location of the detected activity.

Since the CoSMiC Eye system also automatically acquires high-resolution optical imagery, this can also be presented on the user terminals and tablets.

CoSMiC Eye completed successful field trials in Germany and field trials are being prepared for France and Italy.

The objective for this project is to conduct a technical review and evaluation of the CoSMiC Eye system. This project will evaluate its use in North America and the potential benefits it offers.

Deliverables

This project will provide the following deliverables:

- A report will be prepared comparing other technology that uses satellite imagery to monitor pipeline safety and integrity and threats to pipeline operations.
- Several European gas companies have conducted field trials of CoSMiC Eye. Through interviews with these companies, a report will be developed that details the results of these field trials and the conclusions on the benefits of CoSMiC Eye in pipeline integrity management.
- A report will be prepared on the results and conclusions of North American gas companies that will conduct field trials of CoSMiC Eye. Training will be provided on implementing the monitoring of a specific pipeline segment, the operation of the CoSMiC Eye system, and on collecting and interpreting the data and alerts generated by the continuous satellite monitoring

Benefits

Currently, the most widely used methods for pipeline monitoring include foot or vehicle patrols along the pipeline routes and aerial surveillance using small planes or helicopters. These monitoring techniques are costly and limited in both spatial coverage and revisit frequency, with some patrols occurring only once per month. The repeated monitoring coverage of large areas of pipeline ROW in short time intervals and with all weather capability is highly desirable in order to achieve effective monitoring.

Technical Concept & Approach

There are numerous satellites in orbit around the world that have the capability to obtain radar and optical imagery. Researchers will identify and evaluate the state of any satellite-based systems that provide the same function and services as CoSMiC Eye and its proprietary data-analysis algorithms and artificial intelligence.

The CoSMiC Eye pipeline monitoring system has been tested and evaluated by several European gas companies. This project will provide an evaluation of the use of CoSMic Eye by five European gas companies and the preparation of a case study for each.

A critical aspect of this project is in-service field dem- North American field demonstrations will be conducted with the participation of OTD companies. An appropriate pipeline segment and length will be identified and the CoSMiC Eye system will be tasked with monitoring it for a defined period of time. Satellite monitoring of the pipeline segment will occur once every two weeks. If a ROW threat is detected, an alert will be issued to the gas company.

At the conclusion of the field demonstrations, a Final Report comparing the performance of CoSMiC Eye to helicopter or other pipeline ROW monitoring systems used by the gas company will be prepared.

Results

In 2021, multiple kickoff calls were held with project sponsors and the company that owns the CoSMiC Eye system. In the early stages, the project addressed some legal issues.

The project team identified two participating utility sponsors to participate in a pilot program. Separate introductory meetings with these two were held to review how the system works and what is required from the utilities in order to conduct the pilot program.

A detailed test plan was developed.

Status

Tablets are being distributed to participating pilot sponsors with installed software.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Evaluation of Pulling/Shutting Off an Electric Meter

Researchers are investigating the rapid disconnect of electrical service in the presence of elevated natural gas readings within a structure. The project team is evaluating the likelihood of ignition sources resulting from both manually pulling the electric meter and from using an automatic/wireless disconnect device.

Project Description

When natural gas leaks cause elevated gas readings inside buildings, utilities are focused on making the area safe and eliminating possible sources of ignition – including electrical power to the building. However, safety questions remain regarding pulling the electric meter or remotely shutting off the electricity.

In the past, the most rapid method to disconnect electric service has been to pull the meter from its socket, which can create arcing under certain conditions. If there is a large current load through the meter when the mechanical contacts are separated, the probability of arcing is high.

With the deployment of automatic metering systems, remote disconnects for electrical service are available. The assumption is that the remote disconnect contacts will be packaged in such a fashion as to not present an arcing hazard exterior to the device. However, this assumption needs to be properly evaluated.

Another issue with remote electrical disconnect devices is general availability.

This project investigates the rapid disconnect of electrical service in the presence of elevated natural gas readings within a structure. Researchers will evaluate the likelihood of ignition sources resulting from both manually pulling the electric meter and from using an automatic/wireless disconnect device.

Deliverables

The deliverables for this project will be: reporting

- An evaluation of the arcing risk from manually pulling an electric meter
- Suggestions to mitigate this risk
- A survey of smart electric meters that include remote disconnect capabilities
- A survey of retrofit remote disconnect devices
- Information on the arc containment or prevention ability of these devices as captured from the manufacturers and
- Review or development of procedures for field personnel to request a remote disconnect.

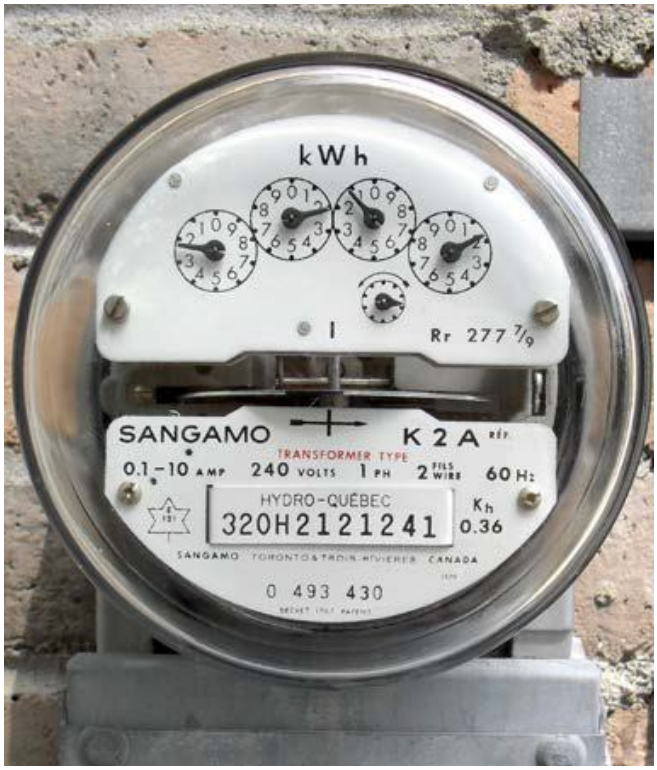
Benefits

Information from this project will serve to safeguard the public, first responders, and utility personnel when investigating suspected leaks within a structure.

Research results will help the disconnect process to be conducted safely and prevent sparks within the structure from acting as ignition sources.

Technical Concept & Approach

The scope of this project is to evaluate the probability of sufficient arcing to present an ignition source during



a disconnect of electric power supply to a structure. Researchers will evaluate both a manual meter pull and a remote disconnect.

Remote disconnect is anticipated to be a lower arcing hazard than a manual disconnect. Still, the issue of how to quickly initiate and complete the remote disconnect must be addressed. It may involve multiple utilities and first responders Remote disconnect must be reasonably quick compared to manual disconnect while not compromising security.

The results of these evaluations will be captured in a report to the sponsors.

The probability of arcing under different load conditions will be evaluated. Suggestions for procedures that can lower the probability will be developed.

Researchers will investigate the available smart electric meters that incorporate disconnect switches. Retrofit wireless disconnect switches will also be investigated. The manufacturers will also be interviewed to capture input on what arc suppression or containment is built into their products.

Any existing procedures for leak investigators to request a remote disconnect will be reviewed. If these do not exist, an outline or draft procedure will be generated for consideration.

Researchers are seeking information on meters, their features, cost, numbers in use, speed of the processes being used, and other issues.

Results

In 2021, the project was initiated with sponsors and researchers developed an electric service disconnect questionnaire focused on processes for shutting off electricity in a gas-filled structure.

Status

The project team is analyzing sponsor survey results and researching both manual and remote disconnect processes and procedures.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Underground Valve Key for Damaged Operators

This research project focuses on the development of an underground service valve tool that can be used to quickly, safely, and effectively operate damaged and/or rounded valve operators without the need for excavation.

Project Description

Over time, underground steel gas service valves can become damaged and rounded due to frequent operation and/or corrosion. These service valves then become inoperable for traditional service valve keys and require excavation by the utilities to replace and operate.

The goal of this project is to provide a market-ready underground service valve tool that can be used to quickly, safely, and effectively operate damaged and/or rounded valve operators without the need to excavate.

The tool will be designed for service and main line valve operators with or without valve stems ranging in sizes up to two inches. The design will also be compatible with long-handled tools used during keyhole-related projects.

This project involves a major industry tool manufacturer and distributor to enhance the design and ultimately bring the tool to market.

Deliverables

The deliverables for this project include:

- A field-tested product produced by a third-party tool manufacturer prepared to commercialize the tool and
- A Final Report describing the improvements of the design and testing results of the final product.

Benefits

Having an underground service valve shutoff tool that can operate damaged and/or rounded valve operators will allow gas utilities to shut off services more timely in the event of an emergency situation. Also, this tool will reduce the amount of time and effort required to perform routine operations and maintenance on damaged and/or rounded underground service valves that need to be operated.

Among the types of equipment being tested.

Technical Concept & Approach

Researchers and project sponsors will identify the tool requirements (e.g., service valve size, valve box size, valve stem design, etc.).

The manufacturer will design and fabricate a prototype. Researchers will provide guidance on the design and the tool manufacturer will refine and fabricate the prototype for laboratory testing.

Results

In 2021, commercially available underground valve shutoff tools were identified, along with design enhancements required in order to meet project sponsor needs for damaged valve operators.

Investigators procured a two-inch square valve key, which was successfully used to turn below-ground valves under normal operating conditions and is used in this project as a control to compare against other tools used for operating rounded valve stems. The project team also procured two valve tools that are designed for use on rounded valve stems.

Laboratory testing.

Laboratory testing was conducted to determine the amount of torque these tools can generate on valve stems of various rounded conditions. Researchers are reaching out to project sponsors to send sample tools, their field evaluations, and feedback.

Researchers found two commercially available specialized tools designed to operate rounded valve stems and began testing them. Both tools are being evaluated with the purpose of comparing their performance and operation in relation to a standard two-inch square valve key.

One tool is a valve key attachment that employs a series of pins that allow the tool to conform to the potentially rounded shape of a valve stem. The other tool is a valve key attachment whose design allows for placing the tool over the valve stem and provide enough points of contact to turn the valve. Both tools had favorable laboratory test results and were found to be able to operate even severely rounded valve stems.

Multiple trials were conducted for each key to achieve comparable averages.

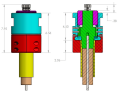
Status

The project team is sending sample tools to project sponsors for field evaluation and feedback.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Hydrogen Blending Impact on Aldyl-A and HDPE Pipes



Research is being conducted to Develop a lifetime-prediction and risk model for Aldyl-A and vintage HDPE pipes pressurized with a natural-gas/hydrogen blend.

Project Description

Gas utilities are increasingly interested in researching Aldyl-A pipes and M8000 pipes. The objective for this project is to develop a lifetime-prediction and risk model for Aldyl-A and vintage high-density (HD)PE pipes pressurized with a natural-gas/hydrogen blend.

Deliverables

The deliverables for this project will be a lifetime-prediction model for Aldyl-A pipe pressurized with a natural-gas/hydrogen blend and an associated Aldyl-A material risk model.

Benefits

Understanding of the impact of hydrogen blends on the existing PE infrastructure is crucial for maintaining the integrity and safety of gas distribution pipelines. Any risk impact due to hydrogen blending needs to be quantified in order for operators to adjust and budget their operating procedures according to the risk impact.

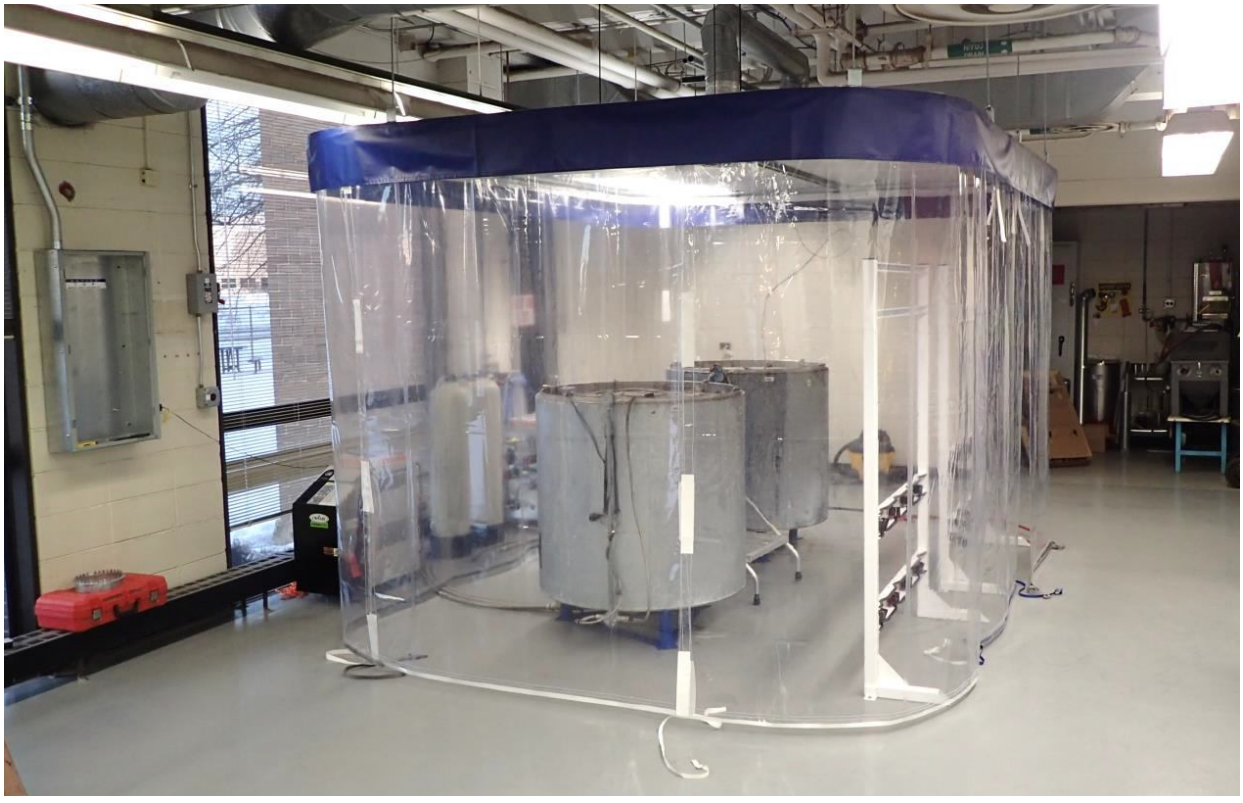
Technical Concept & Approach

Researchers are leveraging previous test rig designs and some on-hand equipment to minimize development costs for the test apparatus.

The testing scope for this project is as follows, with Aldyl-A testing to be executed first, followed by HDPE testing:

- **Long-Term Hydrostatic Strength (LTHS) Tests**

  LTHS tests will be performed at three temperatures, three pressures per temperature, and three replicates per temperature/pressure combinations,



The enclosing test, water tanks, gas cylinder racks, water heaters, water-conditioning system, and ventilation duct are all in place. The tent enclosure confines any gas release and ensures the gas will be quickly extracted through the vent duct at the ceiling of the enclosure.

with methane and methane/hydrogen blend. This task also includes a visual examination to count any existing SCG (slow crack growth) cracks.

- **Dynamic Thermal-Mechanical Analysis (DTMA)**

  Step-DTMA will be performed on a set of nine samples per vintage to obtain activation energies to shift elevated temperature test results to reference temperature results.

- **Tensile**

  Slow strain-rate tensile tests will be performed on a set of six samples per vintage to help establish the ductile and SCG failure slopes of the lifetime prediction model.

- **Oxidation Induction Time (OIT)**

  OIT tests will be performed before and after the LTHS testing to measure stabilizer consumption with and without hydrogen blending.

- **Cross-Polarized Light Microscopy (CPLM)**

  This test is used examine the microstructure of PE for anomalies. For Aldyl-A specifically, this test can detect the presence of large inner-diameter (ID) spherulites associated with the low-ductility inner-wall condition, and to identify pigment windowing, which is sometimes accompanied by large spherulites as well. A CPLM sample will be taken from each pipe before LTHS testing.

- **ID Microscopy**

  Microscopy of the ID of the pipes can identify migration of stabilizers and micro-cracks, which are indicative of the risk bin of the particular pipe specimen. This test will be performed on every pipe specimen before testing.

Results

In 2021, the project team focused on test-rig construction, Aldyl-A pipe-specimen inventory, and material testing.

Technicians completed installing the test rig's water tanks and heaters, tent enclosure, and gas cylinder racks. The gas plumbing components are on hand and will be fully assembled when the pressure controllers arrive.

Quotes for fabrication of the custom-designed pipe caps are being obtained from local vendors.

The research team obtained a sufficient number of Aldyl-A pipes from the pre-1983 vintage and specimens for pressure testing were prepared. Microscopy examination of the pipes was completed in full. Tensile specimens for DTMA and tensile tests were prepared, and DTMA testing is under way. OIT testing of Aldyl-A is also ongoing and material testing is progressing as planned.

Status

The project team is expecting to initiate the first round (Aldyl-A) of LTHS testing in April or May 2022 and the second round of LTHS testing as soon as Aldyl-A specimens are complete.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Advanced Training Technology Consortium 2022

Researchers are identifying advanced training technologies to consider deploying for training new utility workforces. This effort will include identification of training service providers and coordination of an annual workshop or webinar series.

Project Description

As the gas utility industry prepares for 40%-50% of its workforce to retire over the next five years, utility companies need to reassess their training programs to ensure they will be able to meet the training needs of their new workforce. This workforce, at all levels, will need more than the traditional training class that consists of a classroom discussion, presentation, and hands-on practice in a laboratory under ideal conditions. Also, company trainers are no longer entering the training department with 20+ years of experience and field personnel are no longer given the opportunity to train side-by-side with other employees for years before performing work independently themselves.

The use of new training technologies can bridge this experience gap of trainers and expose trainees to more virtual experiences to make up for the lack of actual experience.

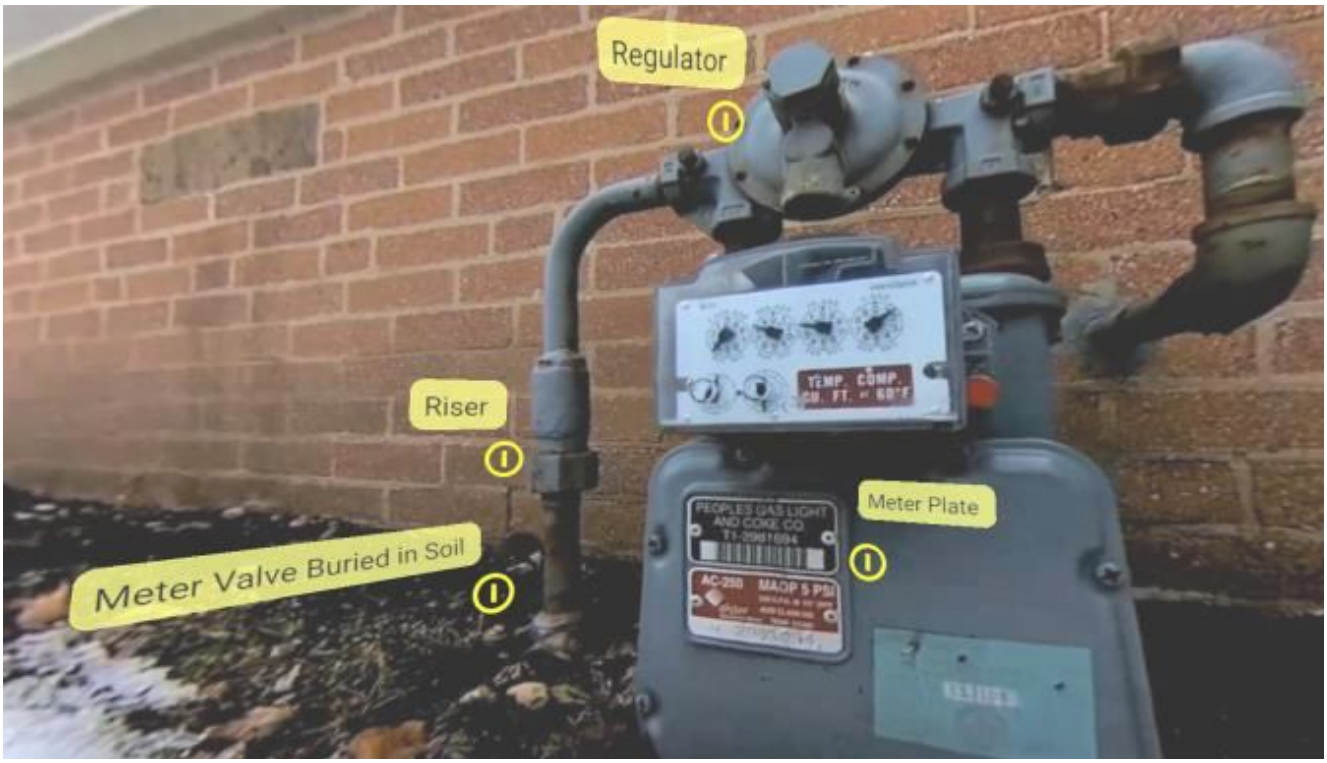
This project builds off of the advanced training technologies identified as part of OTD project 5.20.c *(2020 Advanced Training Technologies Consortium)*, along with identifying new ones for consideration. Also, this project may include developing content for the different training and qualifications solutions identified for project sponsors to pilot test at their organization.

This effort will include identification of training service providers and coordination of an annual workshop or webinar series where project sponsors can evaluate the technologies and meet with industry service providers for each technology.

Deliverables

The deliverables for this project will include:

- A Final Report that details the different types of training technologies evaluated and the contacts for each of the service providers. In addition, this report will include details regarding the hardware equipment, software and any licensing requirements.



360° 3D high-definition video training example with informational hotspots.

- Example training modules for the training technologies of interest
- Coordination of one Training Technologies Conference or webinar series for project sponsors and their subject-matter experts (SMEs) will be conducted. This conference and/or webinar series will include service providers of training technologies of interest.

Benefits

As a result of travel and contact restrictions utilities faced in 2020 and 2021 for their training and qualification programs, some companies struggled to complete the necessary training and qualifications in a timely fashion. In addition, some utility programs are not meeting the learning needs of new employees entering the workforce at all levels of an organization.

Adopting and deploying improved training technologies offers several opportunities and benefits, including the

- Ability to increase learner retention
- Ability to deliver engaging training on demand
- Ability to deliver training to remote office locations without incurring unnecessary travel and lodging expenses
- Ability to have learners experience hazardous job activities in a safe environment
- Ability to maintain consistency among training sessions
- Access to improved data for conducting training effectiveness reviews
- Ability to bridge the knowledge gap more effectively of newer employees
- Ability to introduce new technologies to training departments that may not have the time or opportunity to conduct their own research, and
- Ability to capture "tribal knowledge" of more senior employees and share with new employees in an interactive way.

Technical Concept & Approach

Project tasks include:

- **Identification and Evaluation of New Training Technologies and Service Providers**

  Examples of technologies will be shared with project sponsors and specific technologies will be identified for moving forward with developing example training modules. Some of the training technologies evaluated in OTD 5.20.c will be included for further evaluation.

- **Develop Sample Training Modules**

  These developed training modules will then be pilot tested by project sponsors and their SMEs.

- **Coordinate Training Technologies Users Conference**

  This task will include coordination of one Training Technologies Users Conference, a two-day event or a webinar series depending on travel and contact restrictions at the time. This conference and/or webinar series will be open to project sponsors and SMEs from their organizations. This conference will include presentations and demonstrations by service providers of the different training technologies evaluated.

Results

Activities in 2021 included initiation of project scoping, conducting a project kick-off call with project sponsors, identifying potential training technologies to evaluate, and supporting independent project sponsor technology evaluations.

Status

The following activities are scheduled for execution:

- Complete project-scoping activities
- Establish re-occurring project sponsor working group meeting to evaluate training technologies
- Initiate pilot testing identified training technologies
- Continue to support independent project sponsor technology evaluations, and
- Start identifying potential dates to host the training technologies conference.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Effect of Hydrogen-Blended Natural Gas on the Performance of Gas Meters and Diaphragm-Type Service Regulators

Researchers are examining the effect of hydrogen-blended natural gas on the performance of domestic gas meters in terms of measurement accuracy and intrinsic safety through extensive, long-duration testing.

Project Description

With the inclusion or proposed inclusion of hydrogen-blended natural gas into gas industry piping systems, there are concerns about the performance of service regulators and gas meters and possibly other meter set assembly (MSA) components. The gas operators and regulators require confirmation of whether, within the certain hydrogen concentrations, long-term operation of gas meters and regulators will be ensured without compromising their metrological properties and operational safety.

This project involves a collaboration with parallel project 7.21.j *Assessing Performance Impacts of and Leak Rates on System Components*. A prime directive of both projects is to establish a continuous monitoring rig that can be utilized now and in the future. This setup will prioritize cycle testing of delivery infrastructure such as meters, service regulators, and all components associated with MSAs.

Researchers are examining the effect of hydrogen-blended natural gas on the performance of domestic gas meters in terms of measurement accuracy and intrinsic safety through extensive, long-duration testing.

Deliverables

The deliverables for this project will be reports and data on the long-term impact of using blended gas on the durability of gas meters, service regulators, and other MSA components.

Benefits

This effort provides the following benefits:

- An understanding the long-term impact of using blended gas on the durability of gas meters and service regulators
- Technical insights backed by high-quality testing data that can assist utilities in deciding on a large-scale implementation of blended-gas initiatives in their service area and provide basis for public relation communications considering the components being evaluated are customer facing, and
- Test data specific to gas meters and regulators that are widely used in the North American gas industry.

Technical Concept & Approach

This project includes the following tasks:

Test Apparatus Design and Construction

Researchers will design and construct test rigs/loops with the capability to handle hydrogen/natural-gas blends at typical system pressures. The test rig will consist of separate loops in which durability tests will be carried out using no-blend, 5% hydrogen blend, and 20% hydrogen-blend/natural-gas mixtures. The gas composition, flow rate, and pressure will be controlled through dedicated controller hardware. The test parameters (e.g., pressure, temperature, gas composition, calorific value, and density) will be continuously logged throughout the test period.

Performance Testing

In total, 27 meter samples and nine regulator samples are planned to be tested. This can, however, be modified based on feedback from project sponsors.

- **Durability Test**

  Durability test or accelerated life testing will be carried out on meter and regulator test samples for a period of at least 4,000 hours at a flow rate between 200-300 standard cubic feet per hour (SCFH). Diaphragm meters are examined under 500 SCFH capacity testing standard. Each of the components will be exposed to a total volume of at least 1,000,000 cubic feet of test gas, which translates approximately into volume of gas a residential meter is exposed to in a 20-year service life.

- **Accuracy Test**

  Accuracy testing of meters will be carried out before and after the durability test and also at periodic intervals: every 30 days for the total duration of durability test.

- **Gas Chromatography**

  Gas composition will be continuously measured and monitored using online process chromatographs to ensure the test gas blend composition is maintained. This allows for the detection of any preferential leak of hydrogen through the test setup and components under evaluation.

- **Leak Rate Measurement**

  Periodic leak rate measurements will be taken while the meters and regulators are running on the test loops. The leak test protocol will be programmed into the software that runs the test loops.

- **Normative Service Regulator Tests**

  Tests on the service regulators before and after durability tests will be carried out with air as the medium.

- **Oxidation Induction Time Test**

  Tests on regulator diaphragm material will be conducted before and after durability tests to measure stabilizer consumption with and without hydrogen blending. Surface evaluation and endurance testing will be carried out on regulators after durability testing.

Data Analysis and Reporting

This task consists of analyzing sustained accuracy data and comparing accuracies of samples that underwent durability tests using no blend and blended gas. For the gas meters, accuracies of meters tests with and without blended gas will be compared and the extent of deviation, if any, will be reported. Leak rates from periodic leak tests will be calculated. Performance parameter deviations, if any, of diaphragm regulators will be analyzed in addition to diaphragm material analysis.

Results

A project kick-off meeting with the sponsors was held in September 2021 to present the scope of work, discuss tasks in detail, and answer questions related to types of meters and regulators needed to test, their sampling plan, testing conditions, and data collection. As a follow-up to the kick-off meeting, team representatives reached out to GRDF to discuss their experiences and lessons learned in testing meters and regulators in blended gas.

The research team developed a Microsoft Forms survey to project sponsors that asks a series of questions that will narrow down the range of products for testing.

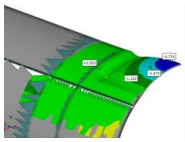
Status

In 2022, project focus is on designing the test rig and finalizing the equipment purchase.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

ARPA-E REPAIR Pipe Renewal Testing



For this project, researchers are performing a literature search and advanced testing identify pipe failure modes and performance criteria for pipe-in-pipe systems. The project, co-funded by the U.S. Department of Energy, is being conducted to provide gas companies with alternative structural repair systems.

Project Description

This research is being conducted to validate a 50-year design life for pipe-in-pipe (PIP) systems to rehabilitate natural gas pipelines in place and in service, resulting in:

The project is co-funded by the U.S. Department of Energy's ARPA-E program to provide natural gas companies with alternative structural repair systems. The OTD cost-share project focuses on laboratory tests as part of the project. This task consists of testing to evaluate the performance of the pipe-in-pipe repair systems under internal pressures.

The tests will be performed according to the requirements of non-metallic composite repair systems for pipelines listed in several industry standards and recommendations.

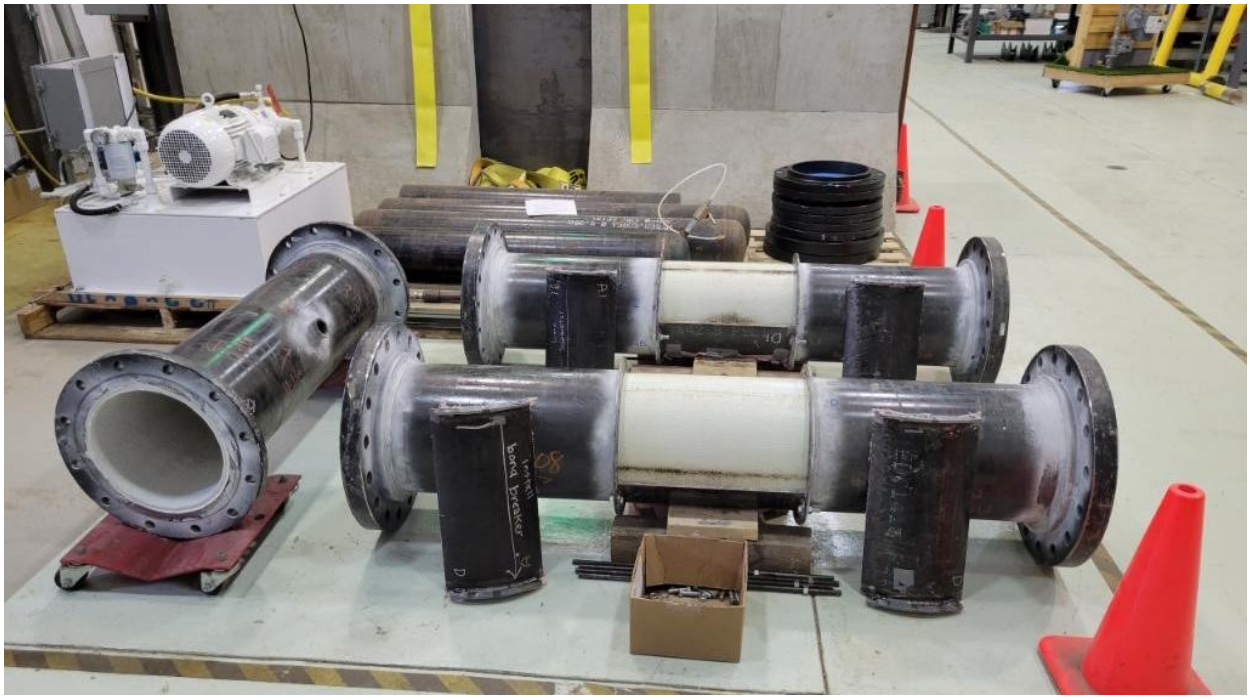
The project The team will develop new and simplified analytical tools that can reliably predict the failure behavior of PIP and can determine the appropriate thickness and mechanical properties of structural PIP for repair of steel and cast iron pipelines in a wide range of operating pressures and conditions. Researchers will advance these analytical tools using the Modified Version of Lame's Equations (MVLE) developed at University of Southern Queensland to establish the fundamental material properties of the structural PIP.

Technical results will be analyzed and translated into technical specifications and regulations that service companies, regulators, and utilities can use for PIP repairs.

Deliverables

The deliverables for this program will be:

1. A comprehensive technical literature review and identification of failure modes and performance criteria for PIPs
2. Analytical models for 50-year performance applied to any materials incorporated in pipeline and PIP systems
3. Testing that addresses all failure modes and performance criteria



4. Full-scale tests for external loads and deformations associated as a minimum with vibrations, deflections, transverse ovalization, axial deformation, bonding/de-bonding at the coating/liner/pipe interface, internal pressure, and puncture

5. Tests for bends, tees, valves, and services

6. Tests for internal load effects that address as a minimum hydrostatic burst pressure, long-term cyclic pressure, full-scale leakage and permeability, and environmental durability, and

Benefits

Due to various technical challenges, gas distribution system operations, and regulations related to new material in the gas pipeline system, few companies have made the technological investments needed to develop cost-effective repair technologies for internal encapsulation of gas pipes without the need for costly excavations. Moreover, many gas utilities have hesitated to implement proposed repair technologies due to the lack of supporting regulations, established best practices, and uniform testing and qualification procedures. This effort will not only identify systems appropriate for use in the gas industry, but also establish an acceptance procedure, as well as the testing facilities and numerical capabilities for future products.

As new products are introduced, competition of various PIP technologies will reduce restoration costs and promote infrastructure renewal across the gas industry.

Results from this project will provide system developers, utilities, and regulators with new knowledge on the testing and modeling of failure mechanisms and systems performance for PIP systems.

Technical Concept & Approach

This research aims to establish a framework of testing and analytical modeling to enable the gas industry to evaluate products to replace or otherwise enhance the performance and longevity of existing natural gas pipeline infrastructure.

The simultaneous development of numerical, analytical, and physical testing protocols will merge attributes of each approach to deliver a comprehensive assessment framework for PIP technologies composed of a wide variety of materials and deposition methods. Identification of critical failure mechanisms (FMs) and appropriate investigation methods will support recommendations for PIP material properties suitable for acceptable design-life performance.

The project begins with the characterization of failure modes and establishment of performance criteria for pipe replacement technologies. The team will develop modeling and test methods based on FMs to analyze and simulate a 50-year design life.

Project tasks include modifying and arranging testing equipment to accommodate the schedule, testing plan, and configurations of the selected repair systems. The testing plan includes establishing the testing protocol and coordinating the testing schedule, number of test samples, and related installation and operational parameters.

The full-scale tests will be performed on 12-inch-diameter host pipe segments with simulated damages or on field pipes removed from service.

While there exist regulations, codes, and standards that document test methods, experimental design, and performance targets for polyethylene and steel pipelines used for replacement of legacy gas distribution pipes, no comparable procedures or regulations are available for qualifying performance of PIP technologies. These repair/replacement technologies can be composed of a variety of materials and depositions methods, requiring a new methodology for assessment and acceptance by the gas industry.

Results / Status

Current project activities focus on sample design and testing procedures according to industry standards as listed in ASME PCC-2 Article 4.1 on *Composite Repair Systems for Pipelines*, Article 4.3 on *Non-Metallic Internal Lining of Pipes*, API Practice 15S on *Reinforced Plastic Line Pipes*, and ISO 24817 *Standard on Composite Repair of Pipework*.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Quality Audit Program for Natural Gas Utility Suppliers

This program provides gas utility operators with a mechanism to collaboratively audit suppliers' quality-management systems. Experts conduct independent and unbiased assessments on behalf of participating operators to provide a reliable and standardized approach for monitoring suppliers.

Project Description

Distribution integrity management regulations encourage utility companies to place a new focus on supplier and supply-chain quality. Identifying threats and mitigating risks starts with the manufacturing process.

Reducing supply-chain risk requires a comprehensive and well-coordinated supplier audit program to ensure that the integrity of the supply chain is controlled and that the supplier is following policies and procedures required by customers and regulators. Supplier audits identify non-conformances in manufacturing, shipping, engineering, and quality processes. Post audit, the supplier and auditors identify corrective actions which must be implemented by the supplier within an agreed-upon timeframe. Future audits ensure that these corrective actions have been successfully implemented.

While the need for enhanced quality audits and monitoring programs is increasing, the availability of resources to conduct these programs is decreasing due to a focus on operations and efficiencies.

This program was created to provide natural gas utility operators with a mechanism to collaboratively audit suppliers' quality-management systems. The program conducts independent and unbiased assessments on behalf of participating operators to provide a reliable and standardized approach for monitoring suppliers.

Deliverables

The deliverables for the program will be reports for each audit and annual summary reports. Only program members are eligible to receive the audit findings reports.

Researchers will also track the performance of suppliers against metrics and will follow-up on identified deficiencies and corrective actions.

An annual workshop is conducted to summarize audit findings and prepare a preliminary list of potential candidates for the following year's audits.

Benefits

Participation in a collaborative audit program provides value in the following ways:

- Creates efficiencies and cost savings by consolidating audits into one program
- Increases the number of audits performed
- Creates leverage and increases influence with suppliers
- Utilizes certified auditors with extensive experience
- Provides high-quality audits due to consistency and standardization of the audit methodology, and
- Allows internal resources to focus on the core business rather than auditing.

Technical Concept & Approach

The audits performed are based on the process approach methodology of the ISO 9001:2015 *Quality Management Systems* per the requirements and inquiries from sponsors. Since 2015, the criteria/scope of the audits changed to focus more on industry standards and utility requirements.

"At Southwest Gas, safety and quality are at the heart of our core values. That's why we appreciate the OTD Quality Audit Program and the additional assurances it provides. With OTD, we know that critical gas carrying component manufacturers have controls in place to ensure the quality of the products we purchase. By ensuring that manufacturers' quality programs are robust and controlled, and that products are only purchased from top-notch suppliers, Southwest Gas can continue to provide safe and reliable natural gas service to the communities we serve."

- Cynthia Davis
Operational Quality Assurance Manager
Southwest Gas Co.

In average, up to 17 processes were covered at each supplier site. These included:

1. Management Review
2. Training
3. Analysis and Improvement
4. Customer processes
5. Equipment/Preventive Maintenance
6. Documentation Control
7. Purchasing
8. Engineering Change Control
9. Internal Audit
10. Corrective Action
11. Production
12. In-process and Final Inspection
13. Verification of Incoming Materials
14. Identification and Traceability
15. Shipping and Inventory Control
16. Non-Conformance Process, and
17. Measurement Tools Calibration.

Each audit may take between two to three days based on the size of a site. Audits are performed by one auditor who may be accompanied by a subject-matter expert. Metrics for both auditors and suppliers are being developed and monitored throughout the program. Examples of metrics include audit report turnaround time, number of corrective actions created, time for corrective action closure, number of overdue corrective actions, etc.

Results

Multiple opportunities for improvement were found at each supplier's site and documented in reports. A new ranking system was created to quantitatively assess suppliers' quality systems and to show the strength and the weaknesses of the organization. These scores can be used as a reference in determining whether the company is making improvements going forward.

To preserve assessment continuity, researchers implemented a hybrid approach for auditing in 2021, consisting of remote audits for business and on-site audits for production processes.

During 2021, the project team finalized the list of suppliers and collected suppliers' feedback regarding hybrid quality auditing via surveys. The team completed schedules for all nine remote and three full on-site audits of manufacturers' sites. Audit reports were prepared and published for all completed audits.

Status

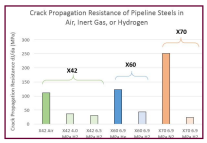
The following activities are scheduled for execution:

- Plan and prepare for audits
- Review and update the audit reports templates and make improvements
- Follow up on the corrective actions that are still pending, and
- Conduct PE Pipe extrusion processes training.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Initial Assessment of Effects of Hydrogen Blending in Natural Gas



This project will establish the experiments needed to assess the impacts of 5% hydrogen-blended fuel on materials in the natural gas pipeline system. A project team will also develop engineering tools to allow an integrity assessment and a safety margin determination of hydrogen-blended gas use.

Project Description

In Phase 1 of this project – conducted in 2014 – researchers assessed the material integrity and operational compatibility of a bounded natural gas pipeline system and its components with a 5% hydrogen-blended fuel to help determine if any system upgrades might be necessary to reduce risk and support gas interchangeability with a 5% hydrogen blend. It also identified future research needs when considering gas interchangeability with blends that contain greater than 5% hydrogen.

Overall, the 5% hydrogen-blended gas did not appear to have a significant impact of the integrity of nonmetallic materials. A literature search revealed that the addition of hydrogen to the natural gas stream is likely to have a significant effect on pipe steels. The data shows that hydrogen gas reduces the fracture toughness, crack propagation resistance, and ductility, and increases the fatigue crack growth rates for pipeline steels and their welds. This is also true for hydrogen/natural gas blends, and even when hydrogen partial pressures are very low, especially for crack propagation resistance. With the introduction of hydrogen, however, comes the need for extensive study, testing, and possible modifications to existing pipeline monitoring and maintenance practices.

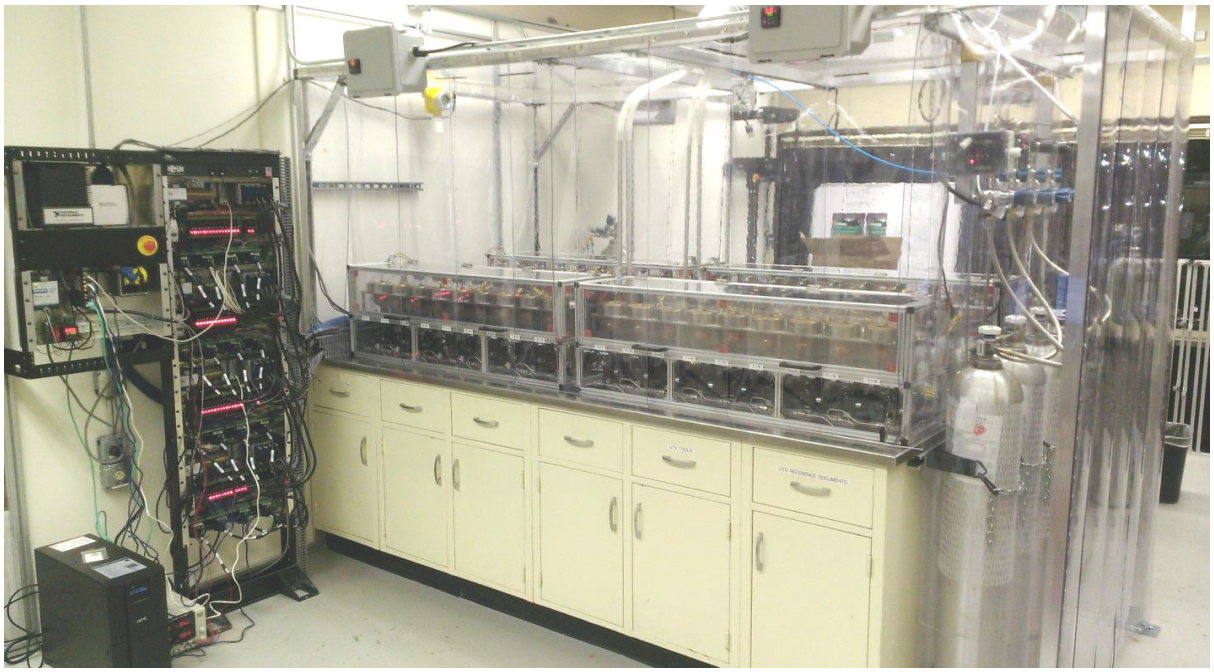
Safety factors for hydrogen gas systems need to be established based on materials tests performed under relevant and site-specific mechanical, environmental, and material conditions without significant extrapolation.

In the current Phase 2, researchers are performing the Design of Experiments (DoE) that will assess the impacts of 5% hydrogen-blended fuel on metallic materials in the natural gas pipeline system. The results of those experiments will provide the properties needed to perform fitness-for-service analysis when hydrogen is present in the system. The materials tested will be those prioritized by utility companies as well as those that represent a significant portion in the natural gas infrastructure.

Deliverable

The deliverables for Phase 2 of this project include:

- Sponsor-approved hydrogen-blend use case to bound testing and engineering modeling requirements



Rig for testing with flammable gases.

- Prioritized pipeline materials to be tested
- Physical testing and design plans
- Final Report and webinar, and
- Detailed plan for Phase 3 to execute testing, modeling, and development of reliability and engineering tools.

Benefits

A project will provide the objective information necessary to: 1) support the pipeline industry's transition to a future requiring increased flexibility, 2) assess the material integrity and operational compatibility of a natural gas pipeline system with 5% hydrogen-blended fuel, 3) help to determine what, if any, system upgrades might be necessary, and 4) identify future research.

Technical Concept & Approach

The Phase 2 project scope includes obtaining system-specific data and materials, formulating a DoE approach, calculating parameters needed to make engineering decisions, and ultimately creating engineering tools to characterize the effect of hydrogen blending on a specific system.

Based on the literature review conducted in the Phase 1 effort, to avoid pipeline failure/rupture due to hydrogen-blended gas effects, there is an essential set of information needed for a specific steel pipeline system:

- Engineering tools - calculations/plots
- Measure material and physical parameters needed to make engineering decisions
- A DoE approach to develop and ensure that the testing matrix covered all the right combinations and minimized the uncertainty and error, and
- Calculated parameters/values needed to make engineering decisions.

In Phase 2, the investigators will establish the hydrogen-blend service and environmental conditions desired. Researchers will obtain vintage metallic pipeline materials and new materials for physical testing. The project team will develop a set of laboratory testing requirements. This will include a detailed review of the available standards and test methods in the literature.

Results

Preliminary test results were promising in that they do not indicate any degradation of the material properties with regard to the ductile failure mode.

Nearly 100 related hydrogen documents, reports, and references were collected for review, with the next step to establish the hydrogen-blend use cases with the sponsors. A use-case survey was distributed to the sponsors. The team also collected, organized, and presented the project use cases. The team collected more than 240 references, focusing on articles that contain experimental methods and results.

Additional effort was conducted to coordinate this project with other national efforts to ensure no duplication with other projects and the most efficient use of resources, time, and samples between all stakeholders.

In 2021, further information was obtained about programs that companies have started to perform hydrogen-blending testing. The project team has also started building equipment for hydrogen testing.

A preliminary draft of the literature review was finalized during the third quarter of 2021. This draft consists of two parts, the first one being well-established and proofed knowledge around hydrogen embrittlement in metallic materials and the second portion being a compilation of journal articles and research studies from the last 20 years. After feedback from reviewers is incorporated, a draft will be distributed among the sponsors of the project.

An updated version with the feedback from reviewers incorporated will be distributed among project sponsors during 2022 Q1. As efforts develop, the team has been aware of the needs being addressed by other entities. With this in mind, work on the Request for Proposal has been purposefully halted to accommodate for capabilities being proposed and built at GTI and to make sure that results will not be duplicated. Coordination with Sandia National Laboratory and their HyBlend effort has started to assure that all the work is being leveraged.

Status

The team continues to collect and summarize related hydrogen documents. Researchers are reviewing responses to a sponsor survey to determine the system parameters for the most likely use cases.

Based on a DoE and use cases, researchers will determine which samples in the Gas Technology Institute pipe library are candidates for hydrogen testing.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Adsorbed Natural Gas Storage Options for Operations Applications

An assessment is being conducted to compare adsorbed natural gas (ANG) vs. pure gas compression for storage and release rates and the quantity of gas stored at various pressures.

Project Description

Bulk storage combined with a gas compressor, gas conditioning, and pressure-regulating station could provide an economically viable alternative to the installation of new pipe to 1) meet the peak gas demands of a system, 2) provide emergency backup for increased resiliency, and 3) offer a means for eliminating the venting of gas when taking gas mains out of service for replacements or repairs.

Activated carbon has a high capacity to reversibly adsorb methane due to its extremely high porosity, which in turn gives it a very high specific surface area. Its surface area can easily amount to several full-sized tennis courts per gram of material. This phenomena is different than absorption, where molecules are drawn into the structure of a solid and therefore are more difficult to be released. The storage advantage of using an adsorbent is most pronounced at lower pressures (below 1,000 psig in most cases) and the rate of pressure rise is different compared to pure compressed natural gas (this reduces the energy required to compress).

The goal is to evaluate adsorbed natural gas (ANG) materials performance with pipeline quality natural gas for bulk gas storage uses.

Deliverable

The deliverable for this project will include a Final Report with performance charts based on laboratory test results comparison tables.

Benefits

Natural gas distribution systems can occasionally be subject to supply shortages when there is new load growth in an area or when weather-related events cause short-term demand peaks. Construction challenges, inadequate return on investment, public pressures, or other barriers can cause new gas main and/or other system capacity improvements to be prohibitive. The strains placed on the system may cause end-user equipment malfunctions and periodic outages.

A technique recently investigated by OTD is the use of bulk compressed natural gas (CNG) storage systems used to supplement the gas distribution system during peak periods. The cost reductions of pure CNG storage containers in recent years instigated the investigation in search of a cost-effective solution.

Activated carbon products are ideally suited for sustainable working capacity performance to store and release mixed hydrocarbon vapors such as gasoline and natural gas. By tailoring an activated carbon adsorbent sorbent from renewable raw materials, one company claims its product will hold up to three times the amount of methane as compressed gas at 230 psig.

The use of adsorbents particularly enhances the gas storage performance at lower pressures, which could improve the overall economics surrounding bulk gas storage investment and operating costs. As a result, significant cost savings potential exists from using much smaller tanks for the same volume of stored natural gas. Other potential applications for ANG

include on-site emergency backup storage, low-pressure recovery, and reuse of flare gas, as well as low energy demand virtual pipeline.

Technical Concept & Approach

- **Literature Search and Materials Specifications Gathering**

  Specifications were gathered to assess potential concerns with the ability to be impacted by odorants, higher hydrocarbons, moisture, and/or other factors.

- **Develop Test Plan and Prepare Laboratory and Data Acquisition**

  A specific test plan will be developed to guide researchers in obtaining the needed data to validate the claims by the manufacturer.

- **Laboratory Testing and Data Analysis**

  This task involves testing bulk-granular material to produce meaningful results at a scale adequate to model performance at larger gas utility application sizes. Data collection will take place at a variety of pressures and temperatures while varying the input and discharge flow rates.

There are several critical questions to be answered in order to fully assess the value of ANG for the scale, duty cycle, and applications. Namely, the cycle life degradation of the material when used with pipeline-quality natural gas is not fully understood. To date, most testing of ANG substrates was conducted with pure methane in which the data shows an attractive less than 5% loss over the life of the adsorbent; but the impact of heavier hydrocarbons being present is not known. Additionally, the effects of other constituents in natural gas such as odorants, moisture, and natural gas liquids will need to be explored.

Results

In 2019, results from previously conducted research on bulk storage solutions were reviewed to ascertain additional use cases and define system supply requirements. Attributes studied included required storage capacity, typical peak period durations, desired storage system recovery times, and desired discharge flow rates. The research team surveyed project sponsors to better understand their needs, desired use cases, and system characteristics to ensure that the project approach will be based on real-world requirements.

In 2020, the project team linked with a chemical manufacturer to discuss scope, schedule, budget, roles, and responsibilities. The project team analyzed new

""Ingevity has leveraged our 100 years of activated carbon expertise to enable adsorbed natural gas (ANG) vehicle technology for light-duty trucks. This technology is already being utilized on bi-fuel Ford F-150 trucks with utility providers across the U.S. We are currently focusing additional resources on ways ANG can be applied to other applications."

- Kevin Moen
Business Development Manager
Ingevity

preliminary testing results that indicate that scale up of ANG from benchscale testing is a significant barrier to developing this technology.

In 2021, the project team designed a custom test vessel that is 250+ gallons in size and rated for over 1,100 psig.

An initial draft of the piping and instrumentation diagram was completed. A system safety evaluation was conducted and areas of concern identified. Strategies for addressing risk were identified. All necessary piping and instrumentation diagrams were completed.

The project team planned the logistics and procedure for filling the vessel with an activated carbon substrate. Additionally, researchers produced a design to address the need for steady flow rates throughout the fill and discharge cycles despite continuously changing vessel pressure. One cycle of filling the vessel in an empty state is planned among the other fill cycles to enable full experimental documentation of the relative benefit of ANG storage compared to CNG storage.

Adjustments were made to the process design of the flow control hardware for dispensing natural gas into and out of the vessel in response to the findings of the safety assessment.

The custom fabricated ANG test vessel was received at GTI laboratories in September 2021.

Status

The remaining components for the project are being ordered. Technicians will assemble the flow-control hardware manifold and control software programming will be initiated. A schedule for the experimental research was created and is under review.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

METHANE EMISSIONS/ DETECTION & GAS QUALITY

Significant initiatives in this area are addressing greenhouse-gas issues, methods for estimating pipeline leak emissions, and remote gas sensing and monitoring. Research teams are also investigating gas-imaging techniques, biomethane monitoring, robots, drones, and various sensors and methane-detection devices.

Results from these efforts help companies to reduce operations costs, minimize environmental impacts, and more cost effectively comply with regulations.

.

Residential Methane Detectors Program

This project developed a comprehensive residential methane detector (RMD) strategy that included market research, technical evaluation of current RMDs on the market, proposed changes to testing standards, and a nationwide pilot program.

Project Description

OTD has been involved in testing and evaluating residential methane detectors (RMDs) for more than 10 years. The program was initiated in 2010 with a first-round evaluation of devices on the market at that time. The goal for that project was to see how the RMDs responded to methane and to a few common household chemicals that might cause a positive interference, meaning a false/positive signal. A second phase project expanded the testing to more domestic and international products.

Researchers found that some commercially available RMDs did respond to lower amounts of methane, well below the current alarm threshold of 25% LEL methane in air. The next phases extended into studying consumer behavior through extensive testing of over 1,000 RMD units from three manufacturers, a year-long pilot study, and further interference and responsiveness testing of new methane detectors emerging on the market. Following these efforts was a White Paper on RMD location and further evaluation of information from the consumer behavior study. The data obtained clearly showed that a methane alarm threshold of 10% LEL was achievable and advisable, and that the presence of a fuel-gas detector in a home will save lives.

In the current phase of the program, several discrete initiatives were conducted, with activities focused on 1) a consumer behavior study to better understand how customers react to potential leaks and 2) the development of a fit-for-purpose standard for residential methane detectors.

These RMD research led to OTD's participation on the National Fire Protection Association (NFPA) 715 committee writing of a new standard that includes a recommendation of a 10% alarm threshold.

Deliverables

The deliverables for this program include: 1) A fit-for-purpose methane alarm threshold determination; 2) a revised standard testing protocol; 3) a consumer behavior study; and 4) pilot study and recommendations.This project also supports the new NFPA 715 *Standard for the Installation of Fuel Gases Detection and Warning Equipment*, expected to be published in 2022.

Benefits

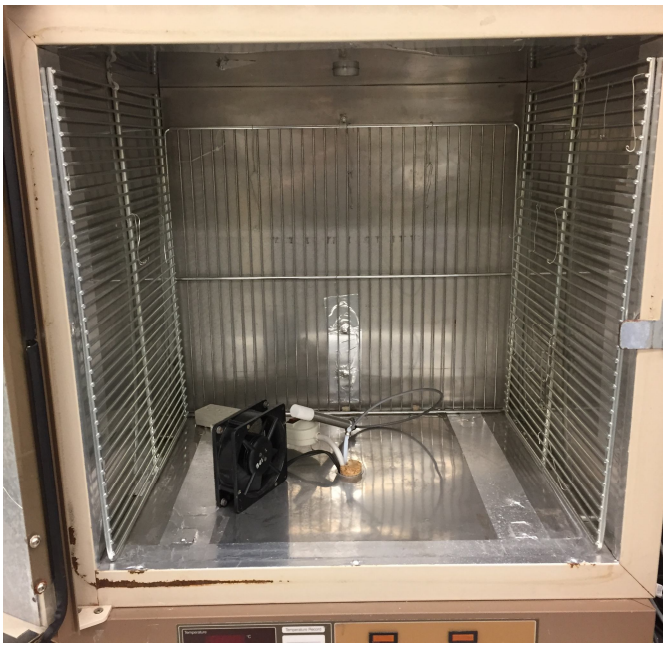
The results of this research allow utility companies to add to their environmental and safety public-awareness programs by offering technically validated information regarding the reliability and enhanced safety that in-home methane detectors can provide.

Technical Concept & Approach

Specific tasks include:

- **Consumer Behavior Study**

  Although RMDs are currently available, there is not widespread adoption and a general lack of awareness of these safety devices exists. This type of study complements existing market research on low customer adoption of gas detectors and customer responses in regards to leaks. The study looks at issues such as limitations in knowledge, consumer motivation, and decision making. These insights help utilities develop appropriate strategies to increase the effectiveness of both natural gas odorant and residential methane detectors.



Environmental test chamber.

- **Development of Appropriate Detection Level and Fit-for-Purpose Standard**

  Commercially available RMDs currently alarm at 25% LEL, which is also the detection threshold that is specified in Underwriters Laboratories (UL) standard 1484. However, the Code of Federal Regulations 49 CFR 192 specifies a gas detection level of 20% LEL in confined spaces, while some states such as New York are even lower at 10% LEL.

- **Pilot Study**

  A pilot program investigated the performance of detectors in actual home settings, consumer responses to alarms, and how effective the detection was.

Results

The first phase of this program determined whether commercially available residential methane gas detectors were susceptible to giving false-positive responses to an assortment of typical household chemicals. Research found that the two most commonly sold devices were the best performers.

In Phase 2, the project team conducted a more comprehensive testing program on commercially available residential methane detectors, expanding the testing program to international products. Laboratory testing was conducted to identify both strengths and deficiencies in these detectors.

Phase 3 was initiated in 2015 with a consumer behavior study. A survey of approximately 1,000 people was completed. This nationwide survey found that overall awareness and ownership of RMDs was almost nonexistent. Subsequent interviews found that respondents were confusing RMDs with carbon monoxide detectors. The study made some suggestions for improvement in regards to natural gas safety education and awareness.

In 2016, the pilot program was initiated and a test plan developed. Three manufacturers were selected based on market share and performance in previous test phases. Approximately 1,000 detectors were installed in residential homes for up to a one-year period. Each participating utility was responsible for installation according to manufacturers' instructions. During deployment, several alarms were reported with one a confirmed methane leak by the utility. The detectors were tested to determine how repeatable the original responses were. Two commercially available detectors had excellent performance. The biggest feedback complaint was the need for cords to power the RMDs, showing that development and commercialization of battery-powered devices is critical.

In 2018, the project team completed the recommended standard revisions to UL and completed testing the next tier of detectors. The final recommendation was an alarm threshold of 10% LEL methane in air. Researchers became involved in drafting a new National Fire Protection Agency (NFPA) standard for installation of fuel gases detection and warning equipment. This effort is still ongoing.

Phase 4 (2019) of the program involved the development of a rationale for recommendations on where to place commercially available residential methane detectors. The implication from literature sources is that placement of a detector should be in the vicinity to the leak source, and high on the wall in a residential space. For many residences, the largest potential leak source is a furnace, followed by a water heater, gas-fired dryer, and kitchen appliances. This encourages placement in basements, garages, and kitchens, which is counter to many manufacturer recommendations.

Phase 5 (2020) involved an evaluation of utility gas safety literature using the lessons learned in the consumer behavior survey. The goal was to make technical recommendations on how to incorporate the use of residential methane detectors into gas safety messaging. Data shows that utilities strongly promote a Learn message, which was a favorable result from the consumer behavior study.

In 2021, the project team became involved in the NFPA committee and discussed the responses to the comments received during the Public Input period that ended May 11, 2021 (Phase 6). The most significant decision from the meeting came around the desire for the alarm threshold to be set at 10% LEL in air. Due to several technical reasons, the committee decided that the standard will be initially published with 25% LEL as the minimum threshold. However, the committee's statement will clearly establish that the next version of NFPA 715 will lower the alarm threshold to 10% LEL. This delay will give UL time to revise UL Standard 1484 and for industry to retune.

Status

Technical testing for this project is complete and reports issued.

Current activities involved the project team's participation in NFPA and UL meetings as needed.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Remote Gas Sensing and Monitoring

Research is being conducted in an effort to develop a device to remotely monitor the level of gases during emergency situations and provide critical information to first responders and gas company personnel.

Project Description

During natural gas emergency situations, first responders need to quickly and efficiently assess the atmosphere within a building or confined space. In this project, researchers are investigating the use of wireless sensors that can be strategically placed to inform first responders of methane concentration. The devices would provide critical information, allowing personnel to determine the concentration of methane inside buildings, sewers, and other structures from a safe distance.

In Phase 1 of this project, researchers developed a local area network of methane sensors to assist leak investigators. The network employs off-the-shelf methane sensors, wireless technologies, and low-cost computing platforms. The communications is short range: from sensor node to sensor node and to investigators' handheld devices.

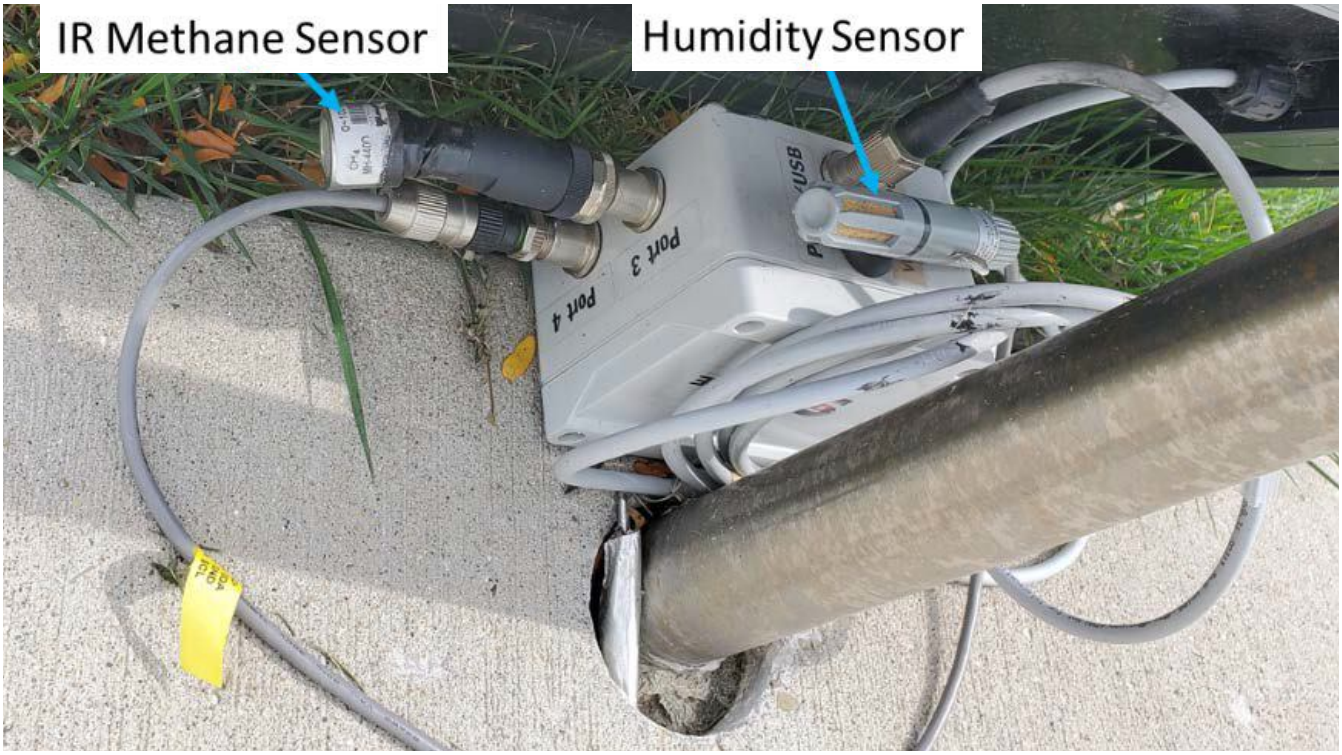
In Phase 2, hardware was modified to provide unattended methane monitoring. This monitor is placed in the vicinity of a suspected (or recently repaired) leak to provide up to five days of unattended monitoring.

The objective of Phase 3 was to develop a system to allow a leak investigator to remotely monitor methane levels at multiple points within a site under investigation. The investigator uses a tablet or phone to see the gas values in real time. Phase 3 involved field tests of the prototype system.

The current Phase 4 focuses on the development of a pre-commercial-ready units that can be tested by sponsors at actual leak sites.

Deliverables

Deliverables include the development of wireless sensor nodes that can detect methane. The project team also developed mesh networking for seven sensor nodes with 100m node-to-node spacing indoors with obstructions. Each sensor node serves a webpage via WiFi that contains the data from all of the sensor nodes. This project includes demonstrations of the prototype system and a report that captures the field-demonstration data, user feedback, and needed modifications.



Outdoor test setup.

Benefits

The safety of workers, first responders, and the general public will be enhanced by being able to monitor methane concentrations remotely. In addition, continuous remote monitoring of various gas levels during known gas leak situations will allow for better and quicker analysis of the situation. The remote sensors can be placed and/or operated in the area of the known gas leak.

Technical Concept & Approach

To improve the functionality of the device, researchers are developing a custom hardware/software solution comprised of a multiple-sensor system and a mobile monitoring device to improve the range and data connectivity of the wireless sensors.

The tangible objective is to produce a prototype of a system to be used by leak investigators and first responders. It will consist of multiple wireless sensor nodes that can be distributed over a site under investigation. The wireless connectivity will be such that the investigator will be able to simultaneously see the data from all nodes using a smartphone or tablet as the interface device.

Demonstrations of the system were performed at test sites to determine if it is a good fit for normal leak-investigation practice.

Results

During Phase 1, the project team developed a set of wireless methane sensors that communicate with one another via a wireless mesh network. Researchers demonstrated the system at several OTD meetings. Subsequently, separate field tests were conducted in 2017.

The prototype system is able to measure methane concentration, temperature, and humidity at multiple points within an area and provide this data to the investigator through a phone or tablet.

The unattended methane-monitoring system consists of multiple sensor nodes that communicate wirelessly with a base station. The sensor nodes were mechanically configured to be inserted into a barhole with minimal exposure above ground. The base station can capture data from nearby sensor nodes, store it, and forward it wirelessly to a server. The data from the sensor nodes is exposed as a web page that can be viewed by any device with internet access. This allows one to check on the methane levels on a site remotely.

For the Phase 1 prototype, each node had access to data from the other active nodes in the mesh network. The mesh allows 100-meter maximum spacing between nodes and supports message relaying to maximize the area that can be monitored. For the Phase 2 prototype, a long-range radio system was adopted that does not require personnel to be present for reading, allowing unattended operation.

Three test sites were offered by the sponsors for field demonstrations in 2018.

In 2020, a subcontract with a sensor manufacturer was finalized and executed. The manufacturer surveyed utilities and captured the basic requirements for applications.

Outdoor testing was initiated on candidate methane sensors to evaluate their stability.

Researchers are investigating:

- An instrument that can measure natural gas concentrations within a specified area, and wirelessly transmit readings to a remote, non-proprietary device, such as a cell phone and
- A device that is installed at work sites that can transmit methane readings to a remote device (e.g., a laptop) to monitor the efficacy of work completed.

A Market Requirements Document was generated and iteratively reviewed by domain and technical experts. The MRD details operation of the instrument across multiple deployment cases and operational modes.

The development has moved into the integration and implementation phase of the development process.

Status

The manufacturer is planning to conduct additional in-depth interviews with customers to review the housing concept form factors.

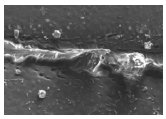
Long-term testing of sensor accuracy and stability continues.

Adaptation of the intrinsically safe hardware platform is under way. The primary deviation is the WIFI module. The manufacturer demonstrated reliable WIFI meshing with a custom WIFI module of up to six devices. The integration of this WIFI module into the hardware platform is ongoing.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Evaluating Leaks from Slow Crack Growth and the Impact on Pipeline Emissions



This project involves an evaluation of how a gas leak evolves over time due to slow crack growth (SCG). The objective is to gain a better understanding of how SCG contributes to methane emissions from distribution pipelines.

Project Description

One of the main sources of gas leaks in vintage plastic pipe is from slow crack growth (SCG). However, it is not known if leaks that develop in vintage plastic pipes remain stable, or if the leak rate increases or decreases over time. This project will provide information regarding the axial growth of a through-wall crack over time, thus helping to complete a model for crack evolution over time.

The current Phase 1 effort focuses on a first-level understanding of how a crack grows in a specific material given different stress conditions and seasonal changes in ambient temperature.

Future phases will focus on developing a more detailed understanding of multiple factors on the evolution of the leaks over time. These additional factors include: gas constituents, soil type, soil condition, burial depth, soil compaction, pipe size, fitting configurations, and temperature.

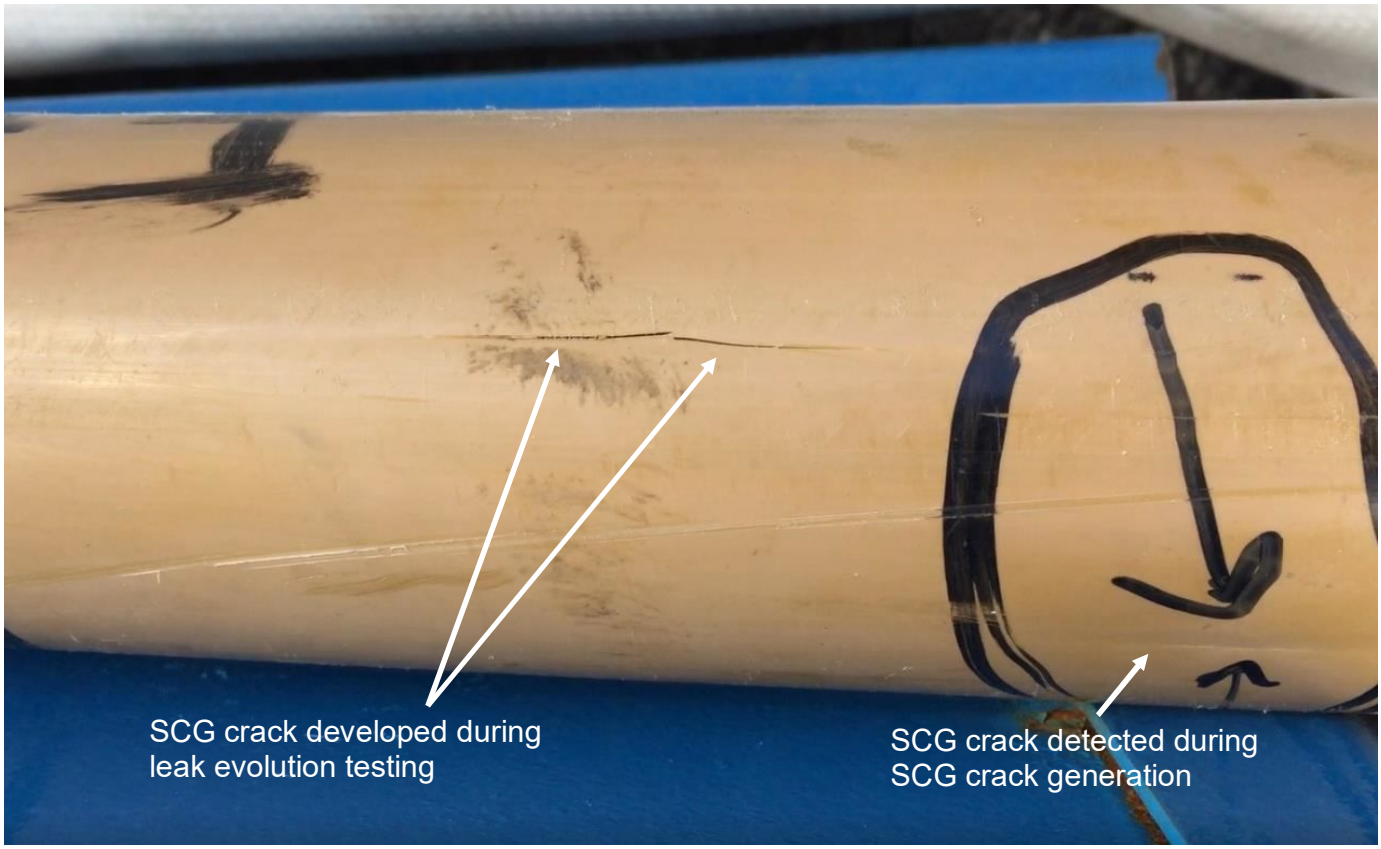
Deliverables

Deliverables include reports detailing testing results and findings, specifically the rate of crack growth as a function of time and seasonal temperature variation.

Benefits

A proper understanding of how leaks tend to develop over time will assist in determining how leak rates change and contribute to overall methane emissions from distribution pipelines. A well-formulated investigation of the various interactions between installation conditions, system pressures, pipe/fitting assemblies, and environmental conditions will be invaluable in developing a framework for more accurately estimating emissions.

Data from this study will provide information that utilities can use to improve leak-repair practices and procedures; therefore, reducing overall emissions.



Technical Concept & Approach

Pipes up to four inches in diameter and two different types of fittings (couplings and saddle tees) are being exposed to hydrostatic pressure testing. Testing is being performed at an elevated temperature (80°C or 90°C) and stress combination to ensure that slit failures are induced. A total of 18 specimens with SCG will be prepared. As soon as the specimens exhibit through-wall cracks, they will be removed from test.

A specially developed leak-flow-rate test rig is enclosed in an outdoor facility. The facility includes equipment and hardware to supply the continuous flow of air and to allow for continuous monitoring and acquisition of data. A by-pass system to allow for the flow of methane is incorporated for the periodic measurement of methane leak rates. Conducting the experiment in this manner eliminates the need for a complex compressor system and the associated safety measures needed for the continuous circulation of methane.

Two stainless-steel chambers were built, each one large enough to house up to nine four-inch pipe/fitting assemblies. Each chamber is arranged for the continuous flow of air through nine individual specimens. The specimens will be placed at the bottom of each chamber built and buried in two feet of soil. Air will continuously flow thorough the specimens at three different set pressures. The leak rate through each specimen will be continuously monitored and recorded by means of an instrumented data-acquisition system for 10,000 hours. Leak rates through the soil will be determined by switching the source gas from air to compressed natural gas, applying pressure to an individual specimen, and then using a Hi-Flow Sampler™ to measure the leak rate.

Potential follow-on phases could include efforts to:

- Expand the experimental data set to additional soil types and conditions
- Conduct experiments at controlled temperature and pressure conditions to substantiate the time/ temperature superposition principles needed to map experimental results to field conditions, and
- Develop a probabilistic model to allow operators to infer the expected leak evolution rate for a leak location given current measurements and additional system knowledge related to the likely pipe, fittings, and burial conditions at the location.

Results

The project team initially designed a leak-evolution test rig and software for the rig. The rig is used to generate pipe samples with small SCG leaks. The generation of pipe samples with SCG leaks began in 2017.

It was found from ongoing tests that the average leak rate of samples can vary between pressurization cycles, therefore, the project team develop data post-processing methods for extracting the leak rate of a sample over time and verification of the flow meter readings.

In 2020, flow testing of two specimens showed high flow rates, indicating that the cracks had grown to exceed a flow rate of 10 standard cubic feet per hour (SCFH). Both pipes were tested for pressure containment, confirming the leaks were at the pipe specimen.

Low flow leak rate assessment, evaluating failed specimens, and continued testing of the remaining specimens was conducted.

Researchers received two rotameters to measure current flow rates from pipe samples. The rotameter setup will be used to inform the measurement range of the samples and provide input for replacing the existing 0-10 SCFH meters with appropriate lower range meters.

In 2021, researchers continued to test the remaining specimens until failure. Two failed specimens were evaluated to characterize the failure mode and indicators of Aldyl-A aging. Both specimens exhibited a typical SCG slit and did not develop additional wall breaches beyond the initial SCG slit. Sulfur deposits were found on both specimens' inner-diameter surface, indicating the migration of stabilizers (anti-oxidants) – a common phenomenon with first-generation Aldyl-A that indicates aging and higher risk of SCG failure.

Preliminary flow tests on 14 Aldyl-A pipes with SCG cracks showed 50% of the samples had high leak-flow rates due to the size of the cracks generated by conventional hydrostatic testing equipment. These flow rates are much higher than average flow rates measured from pipeline leaks from previous studies performed on improving emission factors for distribution pipelines. This raises a concern about consistently generating SCG samples suitable for leak rate evolution testing. The project team upgraded a cathodic protection tester to perform pressure decay measurements to that can detect incipient SCG leaks.

Status

Testing continues on the remaining specimens.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Leak Repair Prioritization

Researchers are developing a method for prioritizing nonhazardous gas leaks, allowing utilities to schedule the repair of leaks based on scientifically sound practices addressing the most critical leaks first.

Project Description

In the natural gas industry, there is considerable regulatory pressure for utilities to prioritize the repair of leaks in order to minimize methane emissions to the atmosphere. However, current methods of measuring leak rates in the field are cumbersome and improved methods are still under development.

The Hi-Flow Sampler™ is commonly used to measure emissions. With this system, measurements can take from 30 to 45 minutes per leak to accomplish. Gas-imaging cameras have the potential to be used to quantify emissions; however, the cameras currently on the market are expensive ($75,000-$100,000). Additional field leak-rate-measurement tools are under development, but are not immediately available in the market.

In the absence of available quantification tools, a method to prioritize leaks in a way that provides a relative ranking of emissions (low, medium, high, etc.) is needed. Such a method would enable utilities to repair the most significant leaks, thus allowing operators to systematically reduce their overall emissions profiles.

The goal of this project is to develop a method of prioritizing nonhazardous leaks – using tools that utilities already commonly own – so that once all safety factors are considered, utilities are able to schedule the repair of leaks that are emitting the most methane to the atmosphere.

In Phase 1, a significant correlation was observed between surface concentrations and emission rates in both sandy and clay soils. Phase 2 focused on testing additional surface types. An emission rate conversion chart will be refined to include the calibration of low, medium, and high leak rates.

A Phase 3 project was proposed that will focus on taking these estimation algorithms a step further by combining the collected data with advanced modeling and a detailed estimation equation developed by the University of Texas-Arlington.

Deliverables

Deliverables include:

- An expanded technique for leak repair prioritization over expanded soil matrices
- A technique for leak repair quantification over cracks in pavement and bar holes
- A revised emission rate conversion chart or charts depending on findings for soil type and bar hole/ pavement testing, and
- A Final Report.

Testing on paved and unpaved surfaces

Benefits

Developing a method that utilities and leak-survey crews can easily employ to provide a relative ranking of methane emissions will allow utilities to prioritize leak repairs based on not only safety but also environmental impacts. Repairing the largest leaks will increase the reduction in methane emissions and improve the utility's overall carbon footprint.

Studies reported that less than 2% of distribution pipeline leaks measured in the studies accounted for 50% of total emissions measured. Being able to identify these and prioritize these leaks for repair can result in meaningful reductions in methane emissions.

A successful project outcome would produce a simple approach to estimate emission rates of distribution pipeline leaks to assist in leak repair prioritization.

Technical Concept & Approach

The intention of the prioritization method is to use tools that companies already have or can easily acquire. For this project, researchers are developing a method for a field survey crew member to use to quickly analyze a leak site and gather a couple of data points (concentration, wind speed, area, etc.) to make a coarse determination of leak rate. This leak flow rate will be a rough estimate with the sole objective of categorizing or ranking the leaks. The method was tested with a variety of leak rates and environmental conditions. The leak flow rate using the conceptual method was compared to the leak rate measured using the Hi-Flow Sampler.

In Phase 2, soil testing at utilities was obtained using the methodology created in Phase 1. The effectiveness of the method was validated against traditional methods. Barhole and pavement testing will also be conducted.

Results

Phase 1 of this project demonstrated good correlations between surface concentrations and emission rates of underground pipeline leaks, and proposed a leak-rate estimation method based on the average and maximum concentration measurements near the leak center. The focus of Phase 2 was to further validate the method using additional controlled release tests and field tests at utility sites.

The project team completed a series of controlled release tests at a leak survey training center to confirm the high correlation. Tests consisted of simulating controlled underground leaks in both sand and clay soil types. Estimated emission rates derived from concentration data were compared to enclosure rates using a Hi-Flow Sampler™. Subsurface simulated leaks were monitored using a Laminar Flow Element (LFE) manifold from which the pressure in the line and the pressure drop across the LFE was obtained. These data were then used to calculate the total leak rate from the buried pipe for quality control purposes.

Researchers completed a field test on distribution pipeline leaks and observed worse correlation compared to the controlled test results, which was likely due to variations in soil type and leak characteristics. The field test demonstrated that the average concentration of 13 measurement points around the leak area provided the best correlation with leak emission rate. To cut measurement time by half, researchers explored an alternative approach of taking the average of only the five central measurement points and achieved similarly good correlation.

Investigators found that having a barhole at a leak center can help improve the strength of the correlation further, especially when using maximum concentration or the five-point average concentration. The results also showed that the correlation between concentration and leak rate was better on paved surfaces than unpaved surfaces, presumably due to lower variability in emission rate from paved surfaces.

After considering all the different approaches, it was recommended that the use of the five-point average concentration after the addition of a barhole at the leak center offers a balance of efficiency and relatively good estimation accuracy.

Researchers also created a method to bin estimated emission rates based on the distribution of leak rates in the system. The 50th and 90th percentile leak rates were used as the transition points between the three categories of high, medium, and low leak rates.

Status

A Phase 2 Final Report was issued in March 2021.

Researchers reviewed a paper that proposed a theory-based method to estimate leak emission rate using surface concentrations. The method could greatly benefit from having the complex algorithm integrated into leak-survey instruments. The next phase of the project can be used to compare the current method with the theory-based method in field tests.

A Phase 3 is planned for 2022.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Evaluation of Gas-Imaging Technologies for Utility Applications

In this project, researchers evaluated the use of gas-imaging technologies for various applications in the natural gas industry, including the use of these tools for methane-emissions quantification and as tools for first responders during leak investigation and grading.

Project Description

With increased pressure to reduce methane emissions from the natural gas industry, measuring leak rates and quantifying emissions have become increasingly important to utilities. Various regulations at the federal and state level are requiring the reporting of greenhouse-gas emissions, and better tools are needed for measurement. While there have been several past OTD projects focused on developing and evaluating methane-detection tools for leak-detection and leak-surveying applications, there has been limited focus on tools for the measurement and quantification of emissions.

Among the technologies tested in this project are the forward-looking infrared (FLIR) camera (which can rapidly scan large areas and identify leaks in real time) and a video camera that monitors, quantifies, and displays explosive/harmful gas leaks in real time. Researchers evaluated these and other gas-imaging technologies for various applications in the natural gas industry. Specific applications will include the use of these tools for methane-emissions quantification and as a tool for first responders during leak investigation and grading.

Deliverables

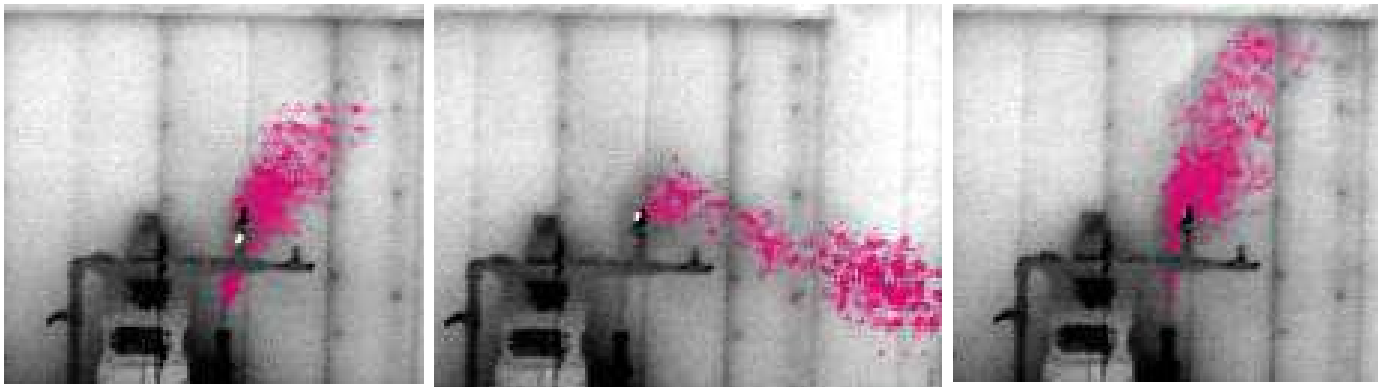
Deliverables include:

- Quantitative measurements of methane leak rates using selected gas-imaging technologies
- A Final Report summarizing the data from the technology evaluation and field demonstrations, and
- Recommendations for manufacturers.

Benefits

Gas-imaging technologies can have the ability to provide for the detection and identification of leaks, as well as enable the quantification of leak flow rate. This

Testing at the pipe farm.



Laboratory testing images.

results in increased safety for customers and utility employees along with added environmental benefits associated with leak repair and/or pipe replacement programs.

Gas-imaging cameras can reduce the time required to obtain a flow rate, enabling utility companies to collect emission rate data from every leak if so desired. Gas-imaging cameras can also help in the leak-investigation process as methane plumes can be visualized and used as an aid in investigating difficult-to-pinpoint leaks. The leak flow-rate information could then be used as a secondary factor (primary factor being safety) to develop leak-repair prioritization plans. As a result, emissions can be optimally reduced while maintaining a safe infrastructure.

Technical Concept & Approach

In this project, controlled tests were performed comparing the performance of the gas-imaging cameras to traditional leak-rate-measurement tools.

A testing matrix was developed to determine the parameters and evaluation conditions for the gas-imaging cameras. These include: distance from the leak, leak rate, leak area, leak source (e.g., pipeline leak, meters), temperature, and other environmental conditions.

cameras. These include: distance from the leak, leak rate, leak area, leak source (e.g., pipeline leak, meters), temperature, and other environmental conditions. Controlled testing was performed in an outdoor pipe farm. The measurements from the gas-imaging cameras are validated using the Hi-Flow Sampler™ as the reference technique.

Two field demonstrations were conducted with utilities on actual utility leaks. Demonstrations helped to determine the utility applications appropriate for using gas-imaging tools. Technologies were tested on various types of leaks and leak sources.

Follow-on research could include evaluations of less expensive and more “field-ready” devices that manufacturers are currently developing.

Results

In this project, several technologies were evaluated in laboratory testing. Each system was run through a similar set of tests to explore the abilities of the systems to locate, image, and quantify emissions from below-ground and above-ground (regulator/meter, compressor) leaks. All systems were tested with similar platforms that included an underground pipeline leak 18 inches below the surface in naturally compacted sand, installed 10+ years prior to testing.

The results of these investigations indicate that, in general, infrared gas-imaging cameras are costly and in need of further development to make the systems portable and rugged and drive detection limits low enough to be useful for distribution use cases.

Additional funding was granted for development of one of the systems tested. Testing focused on understanding the limits of gas-imaging technologies with regards to quantifying leaks under the following conditions: diffuse leaks in sand (i.e., spread over a large area), point-source leaks, diffuse leaks in clay soil, and diffuse leaks in silty soil. Leaks were created and the performance of each unit compared/validated with other tools that have similar detection limitations.

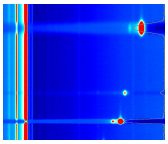
Status

This project is complete. A Final Report was issued in May 2021 that details testing results and describes the products tested.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

On-Line Biomethane Gas Quality Monitoring



For this project, research was conducted to determine if on-line monitoring systems can be used to ascertain key parameters in biomethane being blended into the gas distribution system. The focus was on those constituents that are not routinely monitored by on-line instruments but are critical to gas quality.

Project Description

The introduction of fuel gases from a variety of different sources is becoming more prevalent as states become more aggressive towards incorporating renewable energy into their energy portfolios. Projects focusing on renewable energy also represent important steps to addressing increasing climate challenges.

Many of these gas sources have different trace chemical constituents from those found in natural gas. The need to understand the composition of these gases is increasing as the frequency of their introduction into the pipeline system grows.

The focus of this project is on those constituents that are not routinely monitored by on-line instruments, but are critical to gas quality. The emphasis is on systems with lower cost and shorter analysis times than current techniques.

Manufacturer claims are being addressed through the preparation of artificial standards mimicking natural gas and natural gas with low, medium, and high concentrations of trace biomethane constituents. From the resulting chromatograms, the technologies will be evaluated for sensitivity, selectivity, and repeatability.

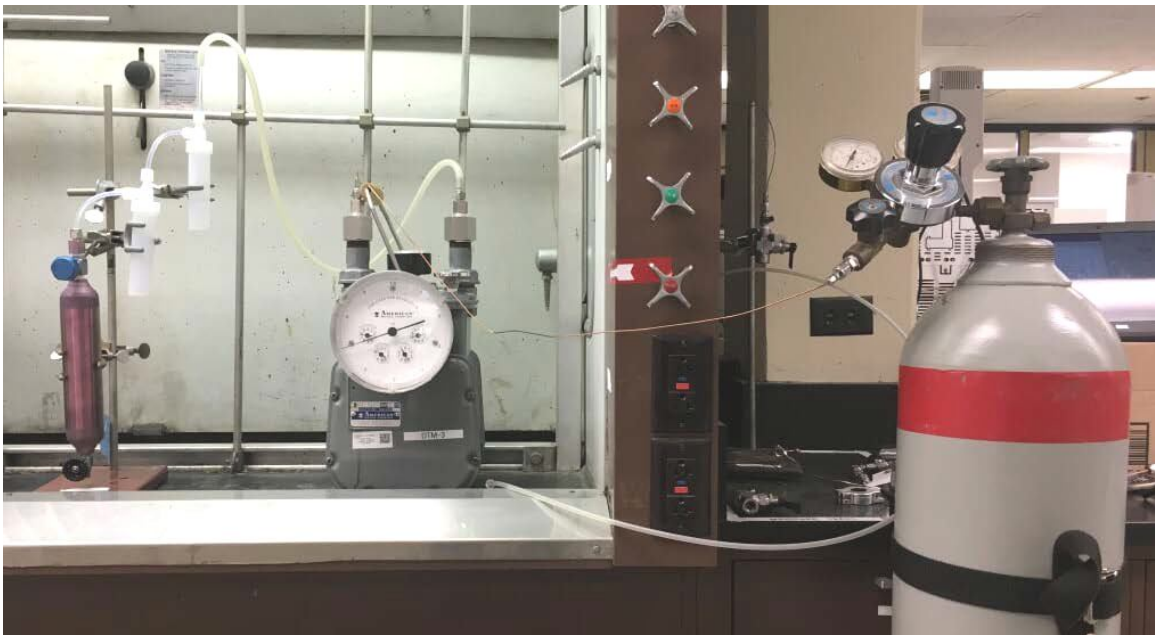
Deliverables

Deliverables include:

- A Task Summary Report to provide guidance on how to monitor the concentration of critical trace constituents in a renewable natural gas stream that are not already being routinely monitored, and
- A Final Report that includes recommendations for any follow-on activities, including a cost estimate, schedule, technology development team, and parameters for the design of an alternative analytical package if none are found available.

Benefits

Monitoring the concentration of critical constituents in the gas stream provides the industry with the capability of protecting valuable underground assets, delivering gas that meets end-usage requirements, and protecting human health. On-line instrument packages are a benefit to both the gas company and the supplier. Results are instantly available instead of having to wait days or weeks for an off-site laboratory analysis. With on-line capabilities, response to conditions could be immediate.



Setup to spike siloxane in methane gas.

Technical Concept & Approach

In this project, researchers conducted a technology assessment of currently available and emerging technologies for their ability to determine the constituents of interest. These included micro-gas chromatographs, optical spectrometers, and mass spectrometers, but also included technologies that are currently being developed by private companies and universities. Technologies were assessed for their analytical characteristics, sampling characteristics, and operational characteristics .

Results

This project developed a survey to determine the biomethane constituents with the highest risk and greatest need for on-line analysis. Five constituents were chosen based on survey feedback and expert knowledge:

- BTEX (Benzene, Toluene, Ethylbenzene, and Xylenes)
- n-Nitroso-di-n-propylamine (and other amines)
- Siloxanes
- Organic arsenic, and
- Halogenated hydrocarbons (e.g., vinyl chloride).

All of these constituents have been found in raw biogas samples from previous projects and the literature, and their presence should be avoided in biomethane.

In Phase 1, this project experimentally validated the market-ready analyzers ranked most promising for monitoring the unconventional trace contaminants potentially found in biomethane injection if cleanup technology failed. The focus was on the constituents that are not routinely monitored by on-line instruments, but are critical to pipeline integrity, end-use integrity, and human health. Several manufacturers agreed to participate in this project.

Researchers prepared six artificial gas standards containing the typical trace biomethane constituents and natural gas interferences based on several factors, including known biomethane tariffs, gas-quality data, known chemical species per constituent, expected interferents, analytical capabilities, chemical supplier capabilities, gas-blending capabilities, and the stability of each component in gas-sampling cylinders.

In Phase 2, each analyzer manufacturer analyzed the artificial gas standards and provided evidence-based assessments on the feasibility of monitoring the trace constituents. Based on the data, each manufacturer proposed product development pathways to overcome identified challenges. The results were competitive and there is no single clear-cut candidate.

Phase 2 of the project began in 2018. Researchers selected the compositions of the four artificial standards for investigation. The standards gases contain 10 of the 13 components in the baseline standard, 10 of the 25 for the low standard, 16 of the 25 for the medium standard, and 17 of the 25 for the high standard. The remaining gaseous components will be spiked by gas blending using a gas blender or headspace injection.

The research team completed investigating the effects of the sampling cylinder temperature on siloxane stability and completed experimenting with valve outlet pressures, which support a higher correlation.

In 2019, researchers secured a portable sensor to safely handle high levels of trimethylarsine (TMA) in the laboratory. The team also received a customized sampling cylinder regulator and started re-trialing the siloxane stability study.

In 2020, a stability study of TMA in an inerted gas sampling cylinder was conducted. No significant loss was observed after 12 days at concentrations between 0.22-0.27 ppmv and standard errors between 0.07-0.12 ppmv. This confirms that the component is less prone to loss in an inerted cylinder than siloxanes, BTEX, and the selected halocarbons. The sample from this study is still contained and will be analyzed periodically to determine a recommended holding time.

To remove ethylbenzene and not the stock cylinders with natural gas components meant ethylbenzene is no longer producible. This does not compromise the investigation because all analyzers have already tested BTEX extensively with calculated sensitivity, selectivity, and accuracy.

Results against the criteria set in showed selective ion mobilities for siloxane, but the signals for the highly volatile components were indistinguishable from the baseline natural gas components. Benzene, toluene, and xylenes were selective due to chromatography and less from ion mobility drift.

Status

A Phase 2 Final Report was issued in August 2021. Phase 3 is under way.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Leak Detection and Repair Modeling for Distribution Systems

Researchers are performing a preliminary evaluation of the feasibility of using the open-source Fugitive Emissions Abatement Simulation Toolkit (FEAST) model to evaluate distribution gas-leak detection and repair programs.

Project Description

Instrumentation used to detect natural gas leaks can vary greatly in capital investment. For example, hand-held units can cost $5,000+, vehicle-mounted units $20,000+, infrared camera units $100,000+, and high-sensitivity complete mobile survey systems $250,000+.

Trial runs of technologies can be expensive; therefore, a modeling approach to initially evaluate the systems may be faster and less expensive. With a fully implemented model, leak detection and repair (LDAR) programs that may have a high initial capital cost, are expensive to execute, or that have been newly developed could be evaluated on a case-by-case basis to determine the potential benefits of implementing new or different LDAR programs.

In this project, researchers are performing a preliminary evaluation of the feasibility of using the Fugitive Emissions Abatement Simulation Toolkit (FEAST) model to evaluate distribution LDAR programs. The FEAST model is available as a full, open-source set of code/modules. Since the model is open source, it can be readily modified and adapted.

The model is driven by a module that simulates leaks from a virtual natural gas field with user-defined parameters – well spacing, leak area around well, and number of components per well – driving the calculation. From this input, individual or multiple sources can be turned on and off and atmospheric transport simulated.

Phase 2 of the project focused on further optimizing the FEAST model for walking surveys, expanding the use case scenarios, and exploring web-based deployment of the model.

Deliverables

The main deliverable from this project will be edited open-source FEAST model modules, including code that is adapted during the evaluation for the distribution-use case. In addition, the project team will modify existing documentation to accompany the changed code so that the model can be used by anyone to study the impacts of different LDAR programs.

A detailed evaluation of the applicability of the FEAST model to distribution will be provided.

A Final Report will summarize the project.

FEAST uses publicly available activity and emissions data and peer-reviewed studies of technologies to model LDAR programs.

Benefits

The ability to evaluate the net value of LDAR programs that includes but are not limited to capital costs of instrumentation, labor costs of use, costs of repairing leaks, and the value of the gas lost/not lost before implementation has the potential to save companies significant time and money with regards to choosing new leak-detection methods and technologies.

Technical Concept & Approach

This project includes three major tasks:

1. To collaborate with project sponsors to gather data on current LDAR programs
2. To use the existing FEAST model to evaluate the potential for adaptation to distribution systems and the amount of effort needed for that adaptation, and
3. To attempt a test run of the preliminary distribution system FEAST model using existing economic modules with two distribution LDAR program scenarios.

The information gathered on the leak field is being used to inform the numerical modeling of the leak-field scenarios.

The feasibility of incorporating a number of scenarios/ parameters for simulating leaks and atmospheric transport were examined. These might include representing net value based on per mile of a particular type of pipe basis, a number of residences (i.e., number of meters), or the number of industrial facilities per square mile.

The form of the FEAST model that is currently available for download incorporates a particular model (i.e., set of equations) to simulate atmospheric transport away from a leak. Researchers expect that initially this model can be used to accurately simulate *above-ground* leaks in distribution. However, for *below-ground* (more diffuse) leaks, the project team will conduct a preliminary investigation into the feasibility of using a more advanced atmospheric transport model that may more precisely represent such leaks.

The performance of a modified FEAST model will be evaluated by attempting to run the model with existing distribution leak data anonymously provided by sponsors, from the literature, and from existing data.

Phase 2 focused on further optimizing the model and developing it for other use-case scenarios, such as mobile surveys. Extensive model-sensitivity tests were conducted to determine the influence of different parameters on model output and evaluate model performance.

Results

During Phase 1, the project team significantly modified modules to simulate a distribution pipeline network. Researchers adapted the model to represent a distribution network grid with leaks detected via a walking survey using a handheld tool. This established a base case for modeling the distribution of leaks generated, detected, and carried over from year to year.

Simulations on FEAST-D show that leak survey with handheld sniffers have very good probability of finding leaks while truck-based leak survey may miss small leaks. Drone-based surveys are suitable for finding large leaks.

The project team was able to successfully generate new leaks in random locations while simulating different survey intervals, with varying ability to locate leaks via walking surveys.

The 2-D grid matrix layout was changed to a 1-D array layout, which allows the system to be represented by total miles of pipe instead of square area. This greatly enhances the performance and ability of the model to represent a wider number of systems. The model was automated to run all survey frequencies and produce graphics for quick analysis and comparison of different model run scenarios. In addition, an initial vehicle-based survey module was developed to begin exploring this methodology.

In 2020, researchers completed a literature survey across four major areas of research related to methane leaks from underground distribution systems: aerial emissions detection, conventional field measurements, truck-based leak detection, and the physical properties affecting leakage.

Development, analysis, and detailed documentation of the FEAST-D model was completed in 2021. Three major methods were considered and simulated for model evaluation, including EPA Method-21, truck-based, and drone-based leak-detection approaches. With the release of FEAST version 1.0 earlier this year, the technical task work of this Phase 2 project is complete.

Status

A Final Report for this project is in development.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428

Methodology to Estimate Flow Rate of Aboveground Leaks Using a Soap Test

Researchers are evaluating a methodology using a soap test to characterize and estimate the flow rate of a leak on aboveground assets at 60 psig or less. This information will be used to help operators better estimate emissions from their assets.

Project Description

One of the largest contributors to emissions for a natural gas distribution company is from meter set assemblies (MSAs). Typically, these leaks are small, nuisance-type leaks that are located at threaded joints of meter-set components.

Currently, a common industry practice to characterize aboveground leaks as hazardous or nonhazardous is to utilize a soap test. If the leak is within close proximity to a building (within three feet) and the leak is strong enough to blow the soap off, as opposed to forming bubbles, then the leak is classified as hazardous. If the leak forms bubbles, then the leak is classified as nonhazardous.

The goal of this project was to evaluate a methodology using a soap test to characterize/estimate the flow rate of a leak on aboveground assets at 60 psig or less. The original scope of this project was to determine the point at which the flow rate is too large for bubbles to form when sprayed with a leak solution. After initial tests, this scope was changed to study bubble formation at flow rates between 0.1 and 5 scfh.

Additional testing was requested in a laboratory setting. There is a desire to understand the transition of foam to bubbles when a soap solution is sprayed on a leak on a threaded fitting. Concentration measurements of the leaks were also requested for characteristic comparisons of flow rates to emission concentrations.

Deliverables

The deliverables for this project include a detailed testing report that documents the flow rate at which various soaps are blown off from a leak, enabling an easy field characterization of emissions.

Benefits

Currently, emission estimates for aboveground distribution assets (e.g., MSAs) are estimated and reported using an emission factor that was developed by OTD in a study completed in 2009. The emission factors provide an average annual emission rate for the entire MSA facility.

This method allows for easy calculation of total estimated annual emissions from MSAs by multiplying the emission factor times the total number of assets. However, using this methodology, efforts taken by companies to reduce emissions through faster repairs of leaks, improved maintenance procedures, etc., cannot be recognized without developing new emission factors, which can be a costly and somewhat lengthy endeavor. Because of this, there is a drive to move towards a leak-based emission factor, where reporting of emissions is based on actual leaks discovered and repaired, and not the number of assets. This methodology can efficiently estimate the leak rate on an aboveground distribution asset by using a soap test. This will allow operators to estimate emissions from meters in the field without the need for additional equipment.

Technical Concept & Approach

Specific tasks in this project included:

- **Soap Solution Identification/Procedure Review**

  Soap that utility companies use to identify leaks can vary widely. Moreover, the concentration and

mixing in the field by crews can vary as well. A survey of project sponsors for commonly used soaps, and procedures for mixing, was performed.

- **Laboratory Testing of Leak Rates and Soap Bubbles**

  Researchers developed a test matrix to conduct leak testing on the soaps selected. The matrix includes pressure variations and temperature variations (of the soap and atmosphere). A test rig was constructed so that flow testing of a variety of different leak configurations can be simulated. These leaks were primarily on threaded connections as that is the most common location for a leak in the field. The average leak rate will be determined from the testing performed.

- **Field Validation**

  Researchers validated leak flow rates in the field in comparison to those observed in the laboratory. Researchers will perform probabilistic uncertainty analysis of the field-test data.

Results

Initially, laboratory tests were completed to study the effect of leak rates, leak type, and soap solution on bubble behavior during soap tests. The experiments demonstrated that there is a correlation between largest bubble size and leak rate which provided the basis of the estimation method. The tests also showed that leak rate is the most dominant factor affecting bubble behavior in comparison to soap solution and leak type.

A field test to assess the feasibility and accuracy of the soap bubble test for quantifying leak rate was completed. Prior to the test, a set of bubble categories was developed to classify the soap test results, with each category having a representative leak rate. Over the course of three days, 47 previously found residential meter set leaks were visited and quantified. The field trial demonstrated that the soap-test method is viable for approximating leak size.

Based on the field trial, a procedure to establish company/region-specific leak-classification criteria to facilitate the soap-test quantification method was developed. The four-step approach enables companies to develop unique criteria based on available leak-rate data. Preliminary field trial data can be used to generate a new leak rate distribution curve and refine the emission factors if company-specific leak rate data is not available initially. Uncertainty observed when classifying leaks can be used to further update the emission factors using a probabilistic approach. The procedure provides a flexible approach for customizing the soap test for specific company needs and continuously improving the accuracy by incorporating new data.

A method based on existing soap tests for grading leaks was developed to perform leak-rate quantification on aboveground leaks at distribution pressure. The methodology is simple enough to be performed without requiring any special equipment or complex training. The methodology allows the leak-rate estimate to be continuously improved. Field data can be used to generate new emission factors if the initial population data was not specific to the company. As more field data is collected, the emission factor for each category can be adjusted continually to account for the uncertainty in the classification using a probabilistic approach.

The findings show that there was a tendency to overestimate leak rates using the soap bubble test method, which might be partially caused by the higher occurrences of smaller leaks in the sample. More data will have to be collected to better understand the accuracy of the method on larger leaks.

A reduced project scope was agreed upon in 2021. Feedback from sponsors indicated it is important to understand the measurement uncertainty caused by process repeatability and reproducibility. Additional input dictated a closer scoping of requisite equipment and achievable parameters.

Accordingly, testing in Phase 2 will prioritize reproducibility based on line pressure. Controls of seven inches water column and up to 30 psig will be used to observe soap bubble formation. Additionally, a factor of up to 60 psig will be investigated if deemed safe and within the capability of testing resources. Researchers will then use past criteria to assign bubble size to a particular leak grade.

All component parts were identified and acquired, and the testing laboratory space and apparatus setup was completed.

Status

Researchers completed the Phase 2 soap-bubble testing. Photos and videos were distributed to sponsor personnel to obtain their independent rating of the results.

A database of leak grades will be made from tests and then submitted to sponsors to review by their company procedure.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Biomethane Justification Study for Improved/Accepted Gas Quality Standard

For this project, a research team developed a study on the quality, analysis, risk, and compositional variability of final end-use-grade biomethane to demonstrate the viability and safety of biomethane use in natural gas distribution and transmission systems.

Project Description

Researchers are addressing a variety of issues related to biomethane injection in natural gas distribution and transmission pipelines. These include considerations regarding safety, reliability, interchangeability, continuity, and the requirements to keep gas flowing and avoid service interruption.

In this project, a research team developed a study on the quality, analysis, risk, and compositional variability of final end-use-grade biomethane.

The goal is to provide biomethane project developers, producers, and distributors with sound science and clear facts that can be used to reduce uncertainty about technical issues related to biomethane utilization.

Deliverables

The deliverables for the overall project include:

- The most recent tabulation of gas quality data
- A risk assessment of the constituents in biomethane
- A simple risk calculator for pipeline component integrity, and
- A biomethane acceptance justification document.

Benefits

Demand for natural gas is increasing as utilities change electricity production from coal to natural gas and trucking fleets convert to compressed natural gas (CNG). Biomethane derived from landfills, wastewater treatment plants, dairy farms, food-waste processors, and other sources is poised to become an increasing part of the natural gas equation.

Biomethane is an active biogenic fuel of choice and an integral part of the renewable energy solution. Building on current projects to upgrade biogas creates an incentive for both developers and utilities to recover a valuable fuel resource and eliminates release of potent greenhouse gases into the atmosphere.

Biomethane qualifies as an advanced biofuel under the Renewable Fuel Standard, and as a cellulosic biofuel (since 2014) when used for CNG production. These qualifications are leading to wider acceptance and specification by regulators and customers. States and other entities are becoming more aggressive in wanting to incorporate diverse sources of renewable energy into their energy portfolio.

Biomethane is being introduced into natural gas pipelines from a variety of sources, including landfills, wastewater treatment plants, and livestock operations.

Universally established gas quality acceptance standards for biomethane will provide answers to interconnect project skeptics and detractors.

Technical Concept & Approach

- **Data Collection and Mining**

  Data from previous gas quality analyses was thoroughly vetted and tabulated for use in subsequent tasks. Data includes information from laboratory independent gas analyses that would be blinded as to actual source but would be grouped by region and type. Additional data from the literature was added to form a comprehensive catalog of information on biomethane quality.

- **Evaluation of Risk**

  Researchers updated existing risk assessments. Metallic pipe was added to the material matrix. Wherever possible, standard metal pipe corrosion data was used. Data from existing literature studies and laboratory experimentations was included.

- **Development of a Risk Calculator**

  A simple risk calculator for pipeline component integrity was developed.

- **Development of Justification Document**

  The framework of previous guidance documents and reports was used to develop a biomethane justification document that will apply across the U.S. and Canada. This document:

  1. Makes specific recommendations of acceptance criteria for biomethane based on assessments of the raw biogas feedstock
  2. Discusses monitoring instrumentation and techniques, and
  3. Explains monitoring periodicity and why it is needed.

Results

Biomethane – or, Renewable Natural Gas (RNG) – is pipeline-quality gas that is fully interchangeable with natural gas. It is derived from raw biogas after the biogas is cleaned of impurities. The raw biogas starts out containing varying amounts of methane with carbon dioxide and other gases, along with small amounts of trace constituents. When it is upgraded for pipeline injection it contains very high concentrations of methane and can be considered cleaner than natural gas because the impurities are removed in a properly operating gas processing plant.

RNG is considered a "carbon neutral" energy source because the carbon dioxide released by its combustion comes from carbon contained in recently living biomass. RNG is being positioned to become an important part of meeting renewable energy challenges in North America as evidenced by the growing number of states with renewable energy goals. This type of gas is already being accepted and used in many parts of the United States and Canada. This project demonstrates that RNG can be cleaned to specifications meeting or better than typical pipeline specifications as found in publicly available tariff specifications on gas quality.

In this project, researchers took a dataset of RNG constituent concentrations and compared it to both a natural gas dataset and a summary of typical natural gas tariff ranges. A technical justification document was created showing these comparisons through examination of the middle quartile ranges for RNG, geologic natural gas, and the interconnection tariffs. The data show that biogas cleanup technology that is working properly can remove these contaminants down to levels well below common tariff limits. Many RNG tariffs reference an upper level much higher than concentrations seen in the upgraded gas.

The data was also used to create a simple risk calculator. If the biogas is not properly cleaned, or if there is breakthrough from the gas cleanup, some risk can occur. The calculator takes user-inputted data on concentrations of RNG/biomethane gas constituents found in a gas stream and calculates a risk to five categories of pipeline infrastructure materials of construction.

In comparison to geologic natural gas, RNG is much cleaner. Some constituents are less of a risk because the levels are much lower, or the constituent is not present. Methane content is watched closely in RNG, but only because it is the major contributor to the energy content of the gas and other alkanes (ethane and higher) found in geologic natural gas do not exist in RNG.

Status

This project is complete. A Final Report was issued in June 2021.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Drone-Based Methane Detection

The objective for this project is to identify unmanned aerial vehicle (UAV, drone) platforms that can be used by utilities to detect methane/leaks on natural gas distribution and transmission systems.

Project Description

New technologies and techniques of methane/leak detection are being introduced on a continual basis, with advancements moving from handheld devices to mobile platforms such as vehicles and unmanned aerial vehicles (UAVs).

UAVs for methane detection are still in the development stages for use in the natural gas industry. This project involves a preliminary assessment to determine the applicability of UAVs for detecting distribution methane leaks.

Several off-the-shelf UAV-based methane systems are currently on the market; however, their applicability to distribution use cases is uncertain. In particular, most systems have focused on identifying large point leaks and may not have the sensitivity for use on distribution leaks. The objective of this project is to identify UAV platforms that can be used by utilities to detect methane/leaks.

Deliverables

The main project deliverables are:

1. Specific recommendations on whether existing UAV-based methane-sensing technology is sufficient for distribution-style leak detection
2. Recommendations on whether new technology can or should be developed, and
3. A Final Report.

Additional phases will be proposed if a technology is identified that needs testing or to further develop the technology if no adequate technology currently exists.

Benefits

The use of UAVs for methane detection presents opportunities for more efficient leak surveying and detection. UAVs present the potential for surveys over pipelines to be conducted faster and more frequently, reducing the risk for potentially hazardous leaks that may arise between typically scheduled surveys.

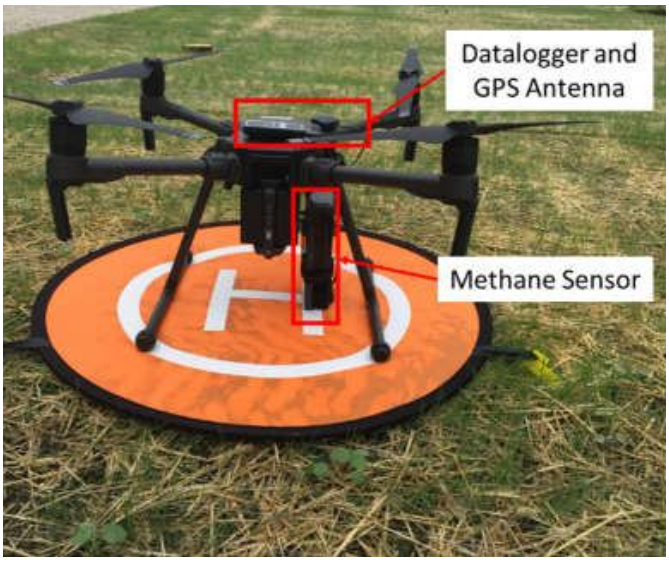
Drones may also allow for remote surveying, which is beneficial when surveying difficult-to-access locations or investigating areas without directly exposing personnel to hazardous gas environments.

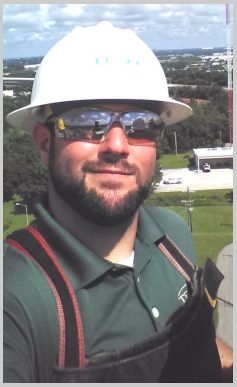
Technical Concept & Approach

The main activities for this project included an evaluation of current protocols, practices, and technology, and an exploration of the potential for using existing UAV-based methane-sensing technology.

Efforts are being conducted to:

- Understand current use cases where a UAV-based methane-sensor would be the fastest and most efficient leak-detection platform
- Identify leak size requirements for detection capabilities
- Determine how a drone could improve current processes
- Identify other use cases that would benefit from the use of a drone, and
- Determine the likelihood of utility company drone adoption.





"Technology advancements in methane sensors and drones have become a great match for us to help find safer and more cost-efficient methods for locating leaks. We are constantly looking to get the best technology in the field, and this project has been valuable with helping us do so."

- Nick Margarone
Corporate Engineering
TECO Peoples Gas, An Emera Com-

Results

Initial tasks focused on information gathering, including a survey of sponsors, an extensive literature review of existing drone technologies, and preparation of an interim report on technologies with recommendations for pathways forward.

Testing was performed on three types of drone-applicable technologies and systems – methane sensors that could be mounted to an existing company-owned drone (sensor only), commercially available combined methane sensor and drone systems (combined platform), and a system being offered by a third-party full-service provider who would handle all data collection and analysis (full-service provider).

The sensor-only testing involved acquiring two sensors that required significant effort before being attached to a drone. One sensor caused the drone to become unstable and was not able to obtain methane concentrations. Another unit required further development to access the data streaming from the sensor. Once deployed to the drone, it is believed that the additional weight likely affected the operation.

The combined platform assessment had more promising results. A unit was able to identify leaks; however, there were limitations to the unit, including the lack of a real-time data display. The unit had to land for the data to be downloaded and analyzed. After the post-processing, several hot spots of higher concentration were identified near the known leaks generated. This system has promise for detecting leaks once the software and real-time data display issues are addressed.

The final system assessment was conducted in collaboration with s a full-service provider. The direct collaboration allowed researchers to have detailed access to the system being tested along with the analytics being used for real-time and post-processed data analysis. An assessment matrix was developed to test the system across a broad range of scenarios involving different sensors, leak sizes, leak locations, flight-grid spacing, flight speeds, and altitudes. The system was able to identify larger leaks under certain scenarios.

The full-service provider testing revealed some important areas where additional testing is needed before drones can be reliably deployed for the identification of leaks. In particular, a thorough study is needed of the impacts of flight-plan grid spacing, flight speed, and altitude on the ability of the drone-based system to find a leak. Further, there appeared to be a difference in the likelihood of detection between above-ground and below-ground leaks, with more below-ground leaks being identified. This could be important and beneficial to the distribution use case since many leaks are on buried pipeline infrastructure.

In 2021 project scope shifted to disaster response. A review of drones and drone-based technology was initiated to cover the industry progress since Phase 1 of the project. The research team will investigate the Hurricane Ida event as a case study for drone-based methane detection and disaster response. Researchers will then compile a list of possible systems to test and finalize a test framework.

Preparations are being made to evaluate systems at a test facility in Florida.

Status

The project team is finalize a test plan for Phase 2 field testing in 2022.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428

Evaluation of 'Point-and-Shoot' Methane-Detection Technologies

A variety of new laser-based "point-and-shoot" methane-detection tools have the potential to provide significant savings in performing leak surveys. In this project, these technologies were evaluated for their effectiveness in locating gas leaks.

Project Description

Laser-based "point-and-shoot" methane-detection instruments allow the user to scan above-ground assets quickly from 20 to 100 feet away. In recent years, several new point-and-shoot technologies have been introduced as commercially available products or instruments that can be rented on a weekly or monthly basis.

Among the new instruments are some that are less expensive, lighter, and more sophisticated than the main technology used today. The objective for this project was to evaluate how well these instruments perform compared to the commonly used remote methane leak detector for initial leak identification.

Deliverables

The deliverables for this project include:

- Details on the use and effectiveness of the tools tested
- Pros and cons of each technology
- Recommended ideal-use scenarios, and
- A Final Report.

Benefits

Laser-based point-and-shoot instruments can provide faster surveying and leak investigation because crews do not have to walk or drive over the survey or potential leak locations. Instead, the technician can stand in one location and scan up to 100 feet in each direction without moving.

These tools also increase safety because the technician is scanning, instead walking, directly over the pipe or aboveground asset. This minimizes movement and the need to access areas with unseen hazards.

The evaluation of these tools will help utility operators in their decision making to provide more cost-effective leak surveying.

Technical Concept & Approach

- **Technology Coordination and Test Design**

  The test parameters for field testing were designed under this task. Researchers designed tests that incorporate a range of leak sizes for both above- and belowground leak scenarios.

Left: Testing of point-and-shoot detector. Right: Mobile leak rig.

- **Controlled Field Testing**

  Researchers performed controlled field testing in the fall of 2018 and the spring of 2019. These tests included a currently used detector as a control to compare new instruments with industry standard equipment. Simulations of different leak sizes in two types of soil were conducted. The testing also included aboveground leak simulations from customer meters and regulators at different sizes to determine relative detection limits of the technologies. Since the controlled releases were metered, the technologies were tested under a range of concentrations and leak flow rates.

- **Leak Facility Field Testing**

  The project team and sponsors will identify two hosts for field testing at a utility training facility for Phase 2. Product evaluations will involve: 1)Testing the ability of the different point-and-shoot techniques to identify leaks, 2) Evaluating the portability, durability, and ease of use of the equipment, and 3)Comparing new technologies to the currently used equipment.

Results

In Phase 1 of this project, researchers evaluated the performance of five laser-based point-and-shoot methane detection sensors. These devices allow for methane detection without having to be inside a methane plume or next to the leak source.

The sensors were evaluated using a repeatable test matrix that involved a series of controlled outdoor tests. The tests included two different sized simulated leaks from a meter set to determine differences in concentration measurements and maximum detection distance for leaks on aboveground assets. The sensors were held at a fixed height and aimed at a transparent bag containing a fixed concentration of methane. Backgrounds tested included brick, concrete, wood painted white, wood painted black, white plastic, black plastic, white siding, blue cinder block wall, untreated wood, mirror, rusty sheet metal, and shaved ice. Additionally, the sensors were evaluated qualitatively in five categories – ease of use, display, portability, field capability, and durability.

A few of the sensors fell short in two key areas – false negatives (not detecting a leak when a leak was present) and detection distance.

The controlled laboratory testing revealed that background materials impacted the measurements from each sensor similarly, with darker materials causing lower concentration readings. The laboratory testing also determined the angle of detection through double-pane windows.

A rain test was designed to show the impact that environmental factors may have on the measurements. For this test, a shower head was used to simulate rain in the laboratory. The methane source was placed directly behind the rain with a light-brown metal cabinet for a background.

In 2020, a test rig was designed and built to simulate indoor meter placement, particularly for multi-unit buildings. The focus of the test was on the concentrations in the air associated with each leak size and whether it can be found using the handheld laser methane detectors.

An additional apparatus was created to simulate leaks around ceiling joists commonly found in basements.

Qualitatively, the new sensors were easier to use, more portable, and had better displays of the concentration.

In 2021, additional testing was initiated on a ceiling joist “leak” setup. In this testing, leaks are generated in three positions along the length of the ceiling joist. Data was recorded to determine if there are any noticeable trends in leak migration along and around the ceiling joists based on the origin of the leak.

The project moved into the blind-testing phase of evaluation. Initial tests revealed less conclusive results on leak detection with handheld laser detectors. It was decided that the needs of the sponsors do not require the detectors to pinpoint a leak but rather provide a clear detection if a leak is present and requires further investigation with a more discerning tool. In lieu of blind testing, researchers performed a series of baseline tests evaluating false/positive detections on the devices when there is no leaking gas present.

A mobile leak rig was developed for initial performance testing of the handheld methane laser detectors. Two meter sets were configured on a mobile platform. Three backgrounds were shifted in and out. Leaks were generated through tubing and threaded connections. Measurements were taken at multiple angles and distances away from the rig. For blind testing the same rig was used with different parameters.

Status

The project team is completing the Final Report.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Impact of RNG on End-Use Applications

Research was conducted to determine the effects of trace constituents in renewable natural gas on end-use applications. Information from prior projects and the technical literature was leveraged to evaluate the impact potential trace constituents may pose.

Project Description

Raw biogas contains more than just methane and carbon dioxide. Metals, halocarbons, siloxanes, and mercury have all been detected in various quantities in renewable natural gas (RNG) sources. These trace constituents in RNG can lead to the buildup of acids, amalgamates, and deposits on burners, nozzles, orifices, and in residential gas lines. However, mitigation technologies can be implemented before RNG is introduced into the pipeline or just prior to end use to prevent future leaks, damage, or hazardous incidents.

This project involved a study that focused on constituent issues to help alleviate concerns with regards to using RNG as a part of today's natural gas supply.

A compilation of gas-quality-related projects found several compounds that could have significant effects if given enough time in the pipeline without taking action. Siloxanes were shown to lead to significant accumulation of silica deposits. During testing, an unvented oven was shown to reach complete failure after 7,500 hours of use.

Mercury is another concern as it is particularly detrimental to the durability of aluminum. Mercury, when brought into direct contact with aluminum, forms an amalgamate and weakens the aluminum. This can have particularly serious consequences if aluminum parts are not replaced in a timely fashion. Additionally, aluminum containing catalysts could be poisoned and no longer function as intended.

Halocarbons are a third example. They can form acids in the presence of water or upon combustion that can result in fluids with slow corrosive properties. Similar to the amalgam formed by mercury and aluminum, the acids weaken iron-containing parts, leading to malfunction and possible failure.

In a previous project, OTD supported the development of a Biomethane Guidance Document to help demonstrate that biomethane is safe to use if properly processed. Results from this project supplement the guidance document by focusing on the impact to end-use applications.

Deliverables

The deliverables for this project include: 1) technical information on potential impacts of trace constituents on end-use applications; 2) recommendations on mitigation/preventative measures and maintenance activities; 3) recommendations for follow-on research, and 4) a Final Report detailing project results.

Mercury damage to aluminum.

Benefits

Small quantities of seemingly insignificant components can pose safety risks as well as contribute to damage in end-use applications (e.g., burner tips, compressor stations, and natural gas-fueled vehicles). Identifying these possible long-term effects can help to diminish future issues and avoid costly repairs and replacements.

Technical Concept & Approach

Several potential constituents and hazards were identified from previous projects. Through this project, researchers tabulated and evaluated each constituent potentially present in RNG with a thorough scientific review and assessment based on chemical, physical, and/or microbial possibility. Chemical and material interactions were examined, along with by-products of combustion.

Results

This project deconstructed gas appliances into their parts and materials and examined the interactions with selected gas constituents. The constituent list came from projects over the past decades that sampled raw biogas and upgraded RNG from farms, wastewater treatment plants, and landfills.

The primary focus of this study emphasized combustion and by-products that were found. Actual combustibility relies on temperature, burner design, and the partial pressures of the products. Widely available materials compatibility charts were used as an initial reference for a large portion of the materials of construction.

The acidic nature of flue gas provides greatest risk for corrosion in metals and refractories and embrittlement in plastics. Low-grade metals are at risk in these environments for longer periods of time. The inclusion of sulfur-containing compounds add a new element in the propagation of corrosion. The formation of sulfuric acid from hydrogen sulfide and sulfur dioxide is a known constituent of corrosion.

For the trace levels potentially present in RNG, the lifespan and functionality of equipment could be lessened over time and lead to failure. Chloride deposition is a rate-determining step in the propagation of corrosion and researchers see most metals and plastics are in some way affected by halocarbons whether it be pre- or post-combustion.

In addition to combustion byproducts, some constituents potentially present in the gas pre-combustion may have an effect. Rubber and plastics are impacted by hydrocarbons present in the gas stream, causing another avenue of potential failure by solvation changing the material characteristics, embrittlement with leaching, or degradation by halogenated compounds. Aluminum is weakened by the presence of mercury.

High-density polyethylene (HDPE) and medium-density (MD) PE are the most common type of plastic used for piping gas to appliances. HDPE and MDPE are not easily damaged by acids but are susceptible to absorption and softening by hydrocarbons, many halogenated species, attack by carbon disulfide, and oxidation by nitric oxides

Metals such as cast iron, carbon steel, and low-alloy steels are all susceptible to corrosion from the formation of acids. This occurs in the presence of moisture with chloride and other halides, moisture with nitric oxides, moisture with sulfur dioxide, or moisture with carbonic acid derived from carbon dioxide.

Stainless steels can be susceptible to several forms of localized attack such as stress corrosion cracking and accelerated general corrosion and pitting in aqueous acidic environments.

Many end-use equipment types use copper alloys in burners, heating elements, and heat exchangers. Attack will happen in moist environments with halogen/halides, and nitrogen and sulfur ions. Some brasses are subject to dezincification in mildly acid solutions which leaves a very weak copper structure that can easily fail.

Of all the components assessed, chlorofluorocarbon (CFC) combustibility is the least understood for end-use applications. CFC-12 has been observed in landfill-derived RNG sites at single ppm levels and is extremely stable and nonflammable. Incomplete combustion of CFC-12 is known to generate toxic byproducts such as dioxins, vinyl chloride, polyaromatic hydrocarbons, and other halocarbons.

A few trends emerge, including that halogens and acids tend to have unfavorable interactions with a majority of the materials. Carbon disulfide, sulfur dioxide, and hydrogen sulfide have issues with rubber and plastics.

Status

This project is complete. A draft Final Report was prepared in May 2021.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Trace Constituent Database

Researchers are developing an online searchable database that will compile natural gas and renewable gas major, minor, and trace constituent concentrations. The database also includes sampling and measurement techniques.

Project Description

In recent years, significant research focused on characterizing the chemical and biological composition of renewable gas (RNG) derived from various biomass sources (e.g., livestock waste, landfills, and wastewater treatment plant sludge). Through OTD-supported projects, researchers collected biogas samples (raw biogas and post-cleanup biomethane) and analyzed more than 300 chemical constituents. These studies were used as the basis for several company-specific requirements for biogas injection. In subsequent years, new feedstock sources were sampled since these original guidance documents were created.

In this project, researchers developed a computer database of gas measurement technology that could be easily accessed by the natural gas industry. It would serve as a source for actual concentration and composition data found in industry samples.

Deliverable

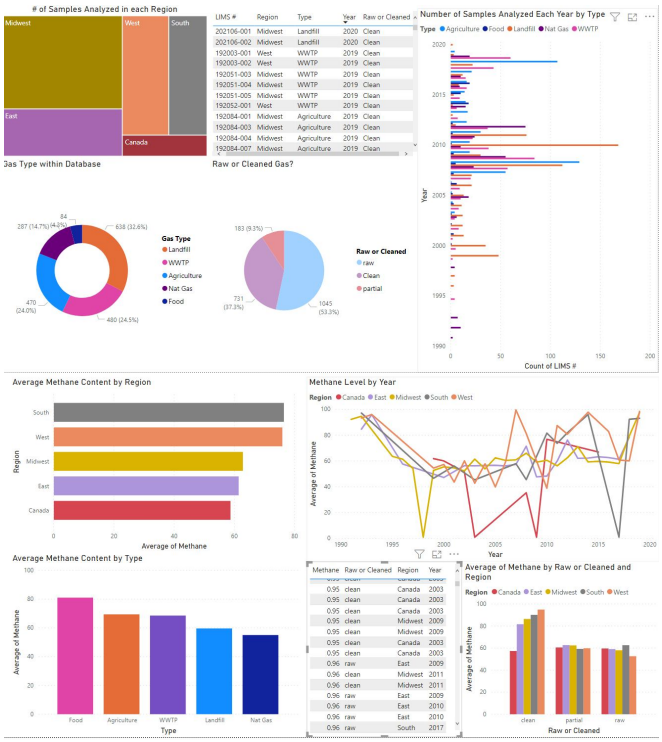
The deliverable for this project is a searchable database of gas constituent concentrations and sample methodology. It is available through the OTD Sharepoint site.

Benefits

No single database of information on methods, measurement-related issues, and actual concentration data for the natural gas industry was available until now. One mission is to aggregate gas-quality information.

This database will also benefit the gas industry and consumers by providing industry workers with reliable knowledge of prevailing technologies to accurately conduct composition and energy measurements.

Screenshots of the report application.



Technical Concept & Approach

Existing data was organized into a master list of data for uploading into the selected database. Data was blinded as to exact origin, but identified as to feedstock and completeness of upgrade from the raw biogas.

Results

The purpose of this project was to create a database containing the natural gas and RNG major, minor, and trace constituent concentrations along with sampling and measurement techniques. This database is intended to provide users with quantitative data of gas constituents to effectively evaluate concentration ranges in RNG deriving from agriculture waste, landfill, wastewater treatment plant sludge and make an equitable comparison to pipeline quality natural gas.

Data from this project was mined from the archives of data files going back to the 1990s and through 2020. Analyses were curated and normalized onto master summary spreadsheets. Unique identification markers for the data include generic region the gas was collected, year, laboratory identification number, gas source, and cleanliness (raw or upgraded).

Eight reports were created covering a variety of target constituents and fuel gas properties. The project team created an online searchable database of trace constituent concentrations along with sampling and measurement techniques. The database and application are directly linked so the application is pulling raw data directly from the database in order to generate reports.

A demonstration of the application was presented to sponsors in November of 2020. A user guide for the report application was developed and sent to sponsors.

Status

This project is complete. A Final Report was issued in June 2021.

Phase 2 of the project is under way to continue adding data and new gas-quality modules.

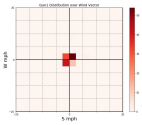
The project team will be adding the fundamentals of the Gas Quality Resource Center onto the scope of the trace constituent database project and combine the two into a fully functional and usable resource for gas quality questions.

The new database would be accessed through the OTD main website and utilize a simple and clean interface with full functionality.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Evaluation and Demonstration of Stationary Continuous Methane-Monitoring Systems



A field demonstration of advanced stationary continuous methane-monitoring systems is was completed. Researchers are evaluating the tools for potential use at a variety of gas facilities.

Project Description

In this project, a research team is evaluating and demonstrating new and advanced stationary continuous methane-monitoring systems for potential use at natural gas facilities such as compressor stations, terminals, gas storage facilities, city gates, and metering and regulating stations. The project involves field demonstrations of commercially available systems as well as a few near/pre-commercial systems.

Deliverables

In addition to monthly summaries of instrument data, deliverables for this project include interim reports and a Final Report detailing results.

Benefits

Information of continuous-monitoring systems will help gas utilities choose the correct instruments for specific situations.

Technical Concept & Approach

A protocol was developed for the necessary metrics needed to evaluate four leak-detection instruments at a metering and regulating station located in California.

Instrument-user requirements were identified and matched with desired sampling methods and platforms prior to instrument acquisition. Sampling methods are the intended process for which field data is obtained (e.g., vehicle survey, walking survey, and continuous monitoring). Researchers gathered user requirements from the perspective of analysts, controllers, site operators, and leak-detection engineers. Understanding how these users will interact with the instrumentation and resulting data will aid in the selection of instruments that meet performance requirements associated with leak-detection limits, data communication, data management, and instrument-maintenance requirements.

Incorporating applicable leak-detection regulations (both existing and pending) is important to ensure that instrument performance will ultimately be able to meet regulatory requirements. Leak-detection instruments were embedded within a robust leak-detection system as recommended in the American Petroleum Institute (API) RP 1175.

The monitoring site is a 500-square-foot station. Local meteorological conditions are very dry and windy with occasional wind gusts up to 100 mph. Sandy soil coupled with windy conditions could potentially create significant dust levels. Temperatures average approximately 100ºF in the summer, with highs peaking at approximately 115º-120ºF. The site consists of two medium-sized taps of similar configuration with operating flows of approximately 570 psi at the inlet and 340 psi at the outlet. Both taps are capable of operating at the same time but are typically designed such that one can be closed for maintenance while the other continues flow. Each tap consists of flanged connections,

differential pressure gauges, pressure meters, regulators, medium and small valves, and numerous small threaded connections around each of the valves and regulators.

Results

Selected instruments were installed at the site in 2019. Controlled-release testing was performed on site to quality check instrument performance. Additional controlled releases are scheduled every six weeks throughout the duration of the project. To accommodate the release tests, the site owner installed a pipe manifold with various orifices which can be individually closed or opened to control the flow rate of a release. The smallest orifice would provide a flow rate of 10 SCFH or equivalent to a sizable leak at a station. Opening multiple orifices at the same time enables larger flow rates.

Prior to the releases, a thorough leak survey was performed and followed up with an application of soap solution at every connection in the facility to check if another source of methane could be present onsite. The leak survey did not find any leak at the station. Further, the elevated concentrations appear to be wind-dependent (stronger in the morning when wind speed is low and lower in the afternoon when wind picks up), thus supporting the hypothesis that there is an open fugitive leak upwind of the sensors.

The controlled releases were conducted for roughly 10 minutes per manifold setting to allow time for the instruments to detect the gas plumes.

Sensor installation took less than three hours since the sensor panels and laser transceivers were pre-assembled prior to site installation. Two laser sensors are mounted on a tripod that has a height of approximately five feet. The heavy-duty tripod was reinforced with sandbags and anchored to the ground for additional durability against the wind.

After installation, conference calls were held with each instrument provider to design data-management, data-storage, and data-visualization procedures.

All data sets were normalized to one-minute intervals. The average concentration over each minute of data was calculated and retained. This data will be used to determine reasonable alarm thresholds for the instruments to prevent an excessive number of false positives.

A different representation of the methane concentration data was developed. The "concentration roses" used previously did not accurately portray the interaction of the methane plume and the wind. The roses essentially tried to display three-dimensional data with only two axes: number of occurrences and direction. The wind velocity was not properly visualized. A casual inspection of a concentration rose can give an erroneous impression of the methane reading source direction. The new representation provides a density distribution of the concentration data points over the wind direction and velocity.

An analysis was performed each month on the instruments' leak-detection performance during controlled releases, leak indications identified by the instruments as well as concentration statistics and summarized in the monthly reports. Additionally, the reports contain visualization of instrument methane concentration as a function of wind direction and speed.

An annual report detailing the performance of the four instruments during the controlled release tests and daily operation in 2019 was delivered in February 2020. The report discusses the creation of new performance metrics to evaluate the sensor performance and provided a table of qualitative assessments to summarize performance of the instruments. The number of leak indications by device is provided.

In 2021, devices continued to provide data through the final monitoring period. The project team communicated with the manufacturer regarding upgrades to its system solution. Upgrades include a greatly improved interface and the availability of 4G cellular hardware for integration.

The team began compiling and synthesizing results and reporting produced by the project for inclusion in the Final Report.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Advanced Leak-Detection Technologies for Grading Leaks

In this project, researchers explored the possibilities for new open-path methane detectors to be incorporated into leak-classification/grading procedures. A project team gathering existing information on the performance of these sensors, created data comparing new methods to existing methods, evaluated any potential safety risks, and produced a recommended procedure.

Project Description

Current procedures for classifying gas leaks are based on well-established methods and the equipment used for leak detection. However, there is an abundance of new methane-detection technologies entering the market that have the potential to improve leak-detection and classification efficiency.

Recent advancements in laser optics and miniature technologies paved the way for the development of a novel open-path methane sensor with potentially high sensitivity. The instrument is currently a prototype weighing less than three pounds that uses passive, open-path sampling (no pump). This system can be used to generate data to look for potential correlations between current instruments and techniques used for leak classification.

In this project, researchers are explored the possibilities for new open-path methane detectors to be incorporated into leak-classification/grading procedures.

Measuring underground leak flow rate with a tarp enclosure and sampler.

A project team is compiled existing information on the performance of these sensors, created data comparing new methods to existing methods, evaluated any potential safety risks of using aboveground measurement to grade leaks, and produced a recommended procedure for using the technology for leak classification/grading.

A Phase 2 of the this project was proposed with the effort focused on answering whether existing leak-grading criteria could be or should be altered to accommodate new technologies.

Deliverables

Key deliverables for this project include:

- Existing data summary
- New technique correlation data
- Leak-classification procedure, and
- Quarterly and Final Reports

Benefits

Open-path sensors have the potential to more quickly examine large areas for leaks, reducing labor costs and increasing efficiency by covering large leak areas.

Two important issues are associated with identifying and classifying leaks are: 1) labor costs required to perform identification and classification and 2) the accuracy and repeatability of the measurement device. Both issues can impact the costs of finding and grading/classifying leaks through potential inefficiencies in equipment that may cause increased labor time to find the leaks or repeated visits needed to find missed leaks.

Some companies are restricted to specific types of technology and, therefore, cannot currently use a whole group of new methane-detection technologies known as open-path sensors for leak identification and classification.

Technical Concept & Approach

A field test was designed that focused on the ability of the technology to 1) quantify concentrations above-ground and 2) quantify concentrations above barholes.

The range of leak scenarios required to demonstrate the effectiveness of the new instruments/methods were limited. Therefore, from the onset of the project, sponsors were asked to participate in real-world testing on real leaks where the new systems can be compared to existing barholing techniques.

Results

The instrument evaluated is based on a prototype originally designed by the NASA Jet Propulsion Laboratory to find methane on Mars as a part of NASA's Mars Rover program. The newer, miniature version is more lightweight and sensitive than traditional instruments of similar size and function. The system uses multiple mirrors and a laser that are coupled to the appropriate analysis region for measuring concentrations of trace methane. The instrument is called "open path" because the laser is exposed to the atmosphere via a porous housing – even though the laser is technically contained within a structure.

In 2019 and 2020, several field tests were conducted to investigate if correlations exist between surface concentrations and barhole concentrations of an underground leak when assessing the grade or severity of the leak. Subsequently, the instrument was re-engineered to have a higher upper detection limit of 500 ppm. In addition, several alternative metrics (average concentration, variance, area under curve) were introduced in this test and yielded much better correlation with leak flow rate compared to maximum concentration reading. The alternative metrics netted better correlation with the leak flow rate, especially when an outlier point is excluded. In addition, a simple leak-detection experiment demonstrated the instrument's effectiveness as an open-path leak-survey instrument. The instrument was able to detect leaks from a distance away and above-ground level.

In 2020, release tests were conducted. Better correlation was observed between measurements and leak flow rates compared to previous rounds. In addition, a set of requirements was drafted for assessing new leak-grading equipment.

Unlike conventional technologies, this instrument was designed with an open-path chamber that relies on passive migration of gas molecules into the sensor. The absence of a probe and pump means that the instrument must be placed close to the ground surface to reliably read the concentration of any gas plume that emanates from an underground leak.

"PG&E works relentlessly to improve leak-detection methods and technologies. Leak grading is a key step of leak surveys since it prioritizes repairs based on safety. It is critical for us to ensure consistency of grading procedures before deploying new tools. This project provided the rigorous foundation needed for that."

- Francois Rongere
R&D and Innovation Senior Manager - Gas Operations
Pacific Gas and Electric Company

Researchers completed a review of current leak-grading standards from literature and collected use case information from participating utilities to better understand similarities and differences between pipeline leak-grading procedures as well as leak-grading compliance variations that occur from state to state.

Empirical data from field experiments and trials show a promising correlation between methane concentration measured by the open-path device and the barhole concentration of an underground leak.

Field testing showed that using the open-path device with the recommended procedure to grade 81 underground leaks achieved the same results as a conventional methane sensor 81% of the time. The use of a wind shield when collecting measurement is recommended to minimize fluctuations to enable operators to derive an average reading more easily.

Status

This project was completed in 2021. A Final Report was issued in April.

Overall, the assessment indicated that the open-path device is a promising tool for leak grading. The instrument demonstrates high portability, high sensitivity, and high frequency, which makes it effective for leak-survey purposes. The recommendation is to proceed with more field trials to establish statistically significant numbers of samples to better understand the uncertainty and repeatability of the method. Additional data collected in the field combined with validation data from conventional methane sensors would provide opportunities to strengthen the correlation established in this study and update the parameters of the model.

A Phase 2 effort is planned for 2022.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

A Framework for Company-Specific Emission Factor Development

The goal of this project is to develop a framework that uses statistical approaches to properly sample emissions from assets for establishing company-specific emission factors. Developing company-specific emission factors is a key step in guiding the industry towards more accurate emission inventories.

Project Description

Gas pipeline regulators rely on emission inventories provided by utility companies in accordance with reporting programs to track emission levels. The approach applied by these programs to calculate emissions from a majority of assets (including meter sets and plastic pipes) is to use national emission factors in conjunction with activity factors (i.e., pipeline length or number of assets). While this approach offers a standardized process, it limits companies' ability to show progress in emissions reduction, since the only way to reduce emissions is to reduce the number of assets or numbers of miles of pipe.

Company-specific emission factors can fill the gap and improve the overall accuracy in characterizing the benefits of their programs. However, a standardized methodology that produces company-specific data and can be performed periodically is still needed. Furthermore, collecting emission rate data is a laborious process. Current hardware for leak quantification is not very portable and lengthy measurement duration makes the process resource intensive when scaled over a large area or numerous distributed assets.

A sampling plan that would generate a statistically significant estimate of network emissions with minimal resource requirements would allow companies to develop company-specific emission factors.

The objective for this project is to develop a framework that uses statistical approaches to properly sample emissions from assets for establishing company-specific emission factors.

Deliverables

The main deliverable will be a framework that guides the development of sampling in a manner that accurately represents each asset, as well as a statistical analysis process for generating company-specific emission factors. A Final Report will summarize the findings and include examples highlighting the application of the framework.

Benefits

A framework for developing company-specific emission factors is a key step in guiding the industry towards more accurate emission inventories. Company-specific emission factors would offer the means of demonstrating to regulators and stakeholders accurate methane emissions reductions resulting from infrastructure upgrades and improved maintenance practices. Additionally, effectiveness of emission-abatement programs can be quantified with periodic revisions of company-specific emission factors.

Technical Concept & Approach

The main objective of the framework is to allow companies to have a standardized approach for planning, collecting, analyzing, and validating data to establish company-specific emission factors. This will allow companies to visualize an emission factor study as a series of manageable steps and focus on executing the tasks.

Determining factors that affect emission rates and categorizing samples by these factors (e.g., pipe material and meter type) is important to recognize emission

differences within an asset type. The project team will provide examples on how different assets can be stratified. Researchers will also review commercially available sampling methods and their measurement uncertainties.

To allow for flexibility in experimental design, rather than prescribing a sample size, researchers will include statistical approaches for assessing the expected confidence level from a given sample size and how well a sample generalizes to the population. The selected approach will produce a representative emission factor for each asset class as the output as well as confidence intervals to represent uncertainty in the result.

Results

Research in this project consists of two methods: Method 1 - Walking Close Proximity Survey Framework (Point of Leak) and Method 2 – Mobile/Remote Survey Framework (Standoff from Leak).

Method 1 includes the sample method, sample plan, data analysis, and framework. The various forms of sampling plans were explored (e.g., pure random, stratified random, and aggregate of multiple geographic samples). Additionally, researchers addressed other statistical sample plans and dynamic sample plans for below and above ground assets.

Method 2 began in 2020 and followed the original 12-month period of performance. Method 2 began with a plan on how a utility would/could start with national data and findings, and then, over time, feed in their own survey data and validations to reinforce or washout the prior national data.

In 2020, researchers found that national studies compared well with the utility example data. The mean, median, and upper and lower 95% percentiles for leak rate of these two groups are similar. The non-hazardous leak rate values the data set were analyzed for unexplainable outliers or extreme values and was log transformed, resulting in a normally distributed data set. Upon review of the extreme values, all of them were deemed as sound data points and not errors or anomalous values.

Two key findings were that when the samples sizes supported categorical analysis, a) there was no significant sensitivity of the leak rate means to geographic operating districts where the leak was found, but b) there was a statistical significance (difference in mean values) to the time interval from when a leak was detected.

The framework in this report allows for a statistically sound study of pipeline leaks using random samples and well-proven field techniques for structuring leak methane concentration measurements and leak flow rate measurements.

The approach can be further refined and improved by continuing to:

- Collect field data leading to lower uncertainty
- Perform random checks for false negatives to identify possible upset conditions in expected leak rates, and
- Analyze and adjust the thresholds or even add new thresholds to further increase the method's predictive accuracy and/or increase process efficiency.

A set of emission factors based on the categorization was calculated by combining the mean leak rates with their corresponding expected percentiles (in a weighted manner) from the error table. This process allows for the assignment of an appropriate emission factor for all distribution buried system leaks regardless of the leak grade, methane concentration data for the category, and leak flow rate measurement data.

The pilot study was successful in developing at framework that uses statistical approaches to properly sample emissions from assets for establishing company-specific emission factors. A method was developed for flagging large leaks for cost-effective measurement and repair to minimize system-wide methane leakage rates that further focuses on strategically and cost-effectively prioritizing repair of non-hazardous leaks.

This approach is compatible with direct-concentration measurement techniques and will also work with remote-concentration measurement instruments such as vehicle-mounted or aircraft-mounted methane analyzers to identify underground leaks in the “large” category where the system provides adequate data quality.

The emission factor framework can be also applied to above-ground leaks, although there is an extra leak-rate estimation method to consider.

Status

The majority of the research is now completed with only some adjustments to be made as the remote prescreening methods and aboveground considerations are added to the framework.

A Phase 1 Final Report was issued in March 2021.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

RMDs - Sensor Drift and False Negatives

Research was conducted to determine if residential methane detectors (RMDs) that experience long-term exposure to low concentrations of methane will exhibit sensor drift resulting in a false negative alarm.

Project Description

A false negative on a residential methane detector (RMD) is the absence of an alarm that improperly indicates methane is not present, when in reality methane is present. Confirming that an accurate response will occur even when the RMD is exposed to low but constant methane concentrations is critical if these devices are to be deployed to the general public or used for gas facility monitoring applications.

As part of OTD's current RMD research program, extensive testing was conducted on three U.S.-manufactured RMD devices with large market shares. More limited tests were done on a few international devices from Japan and Europe. Results show that these devices perform well at 25% LEL and can often alarm down to 10% LEL. Accurate performance at 10% LEL is the critical threshold for the program and the level being recommended.

RMD continuous flow test chamber.

The specific sensors used in RMDs vary with each manufacturer, but, in general, are based on the same scientific principle: semiconductor Micro-Electro-Mechanical Systems (MEMS) technology. Over time, these sensors are known to experience a slight drift and the electronics are adjusted accordingly to ensure appropriate response over the estimated device lifetime. What is unknown is how the RMDs will behave after a long-term exposure to an atmosphere containing a low-level amount of methane, lower than the % LEL alarm levels.

In this project, testing was conducted to determine if detectors will alarm as expected when the concentration rises to the trigger level, or will the constant low exposure to methane cause a drift in the sensor response and create a false negative and fail to alarm.

Deliverable

The deliverable for this project is a report summarizing the data on the responsiveness of RMDs after exposure to long-term and low-level concentrations of methane.

Benefits

Broader use of RMDs can warn customers of increased levels of methane before they reach combustible levels. Having an accurate and stable early-warning system in homes can improve safety and prevent unfortunate events from occurring due to unreported or undetected gas leaks.

Technical Concept & Approach

This project was designed to answer the false-negative question through a series of tests on RMDs previously exposed to low levels of methane.

A new RMD test chamber was designed and constructed with the capability of trickle-flowing methane gas and integrated sensors for monitoring and maintaining methane concentration, relative humidity, and temperature. Trickle flowing the gas is necessary to keep the methane concentration constant and avoid leaks over the test duration.

Continuous methane analyzer.

Safety shutoffs were added to cut off flowing gas if power and/or ventilation is lost. This test setup will be available for use on future sensor projects requiring flowing methane gas.

A minimum of three detectors for each test were tested from each manufacturer. At least three different manufacturers were tested.

Researchers confirmed performance at 10% LEL methane exposure of all devices used in study. Each subsequent test required fresh devices (minimum of 12 devices per manufacturer).

Results

In 2020, technicians completed construction of the test chamber and initial testing was completed.

A continuous gas analyzer was identified as a necessary component for confirming low methane levels and purchased to cover the range of methane concentrations outlined in scope of work (0-5000 ppmv).

All four RMD models underwent initial testing at 10% and 25% LEL methane in air. Exposure testing began for the one-week period with the highest condition point. Three detectors of each brand were exposed for seven days in the new chamber with the flowing gas being monitored by the new continuous analyzer. The detectors were tested at 250 ppmv, 500 ppmv, 1,000 ppmv, and 2,000 ppmv.

No issues were seen with most devices. A single device did not alarm at 10% LEL, but did alarm at 25% LEL after exposure at 500 ppmv methane. All other exposures passed at both methane test levels. Several devices from one manufacturer falsely reported carbon monoxide during the 500 ppmv, 1,000 ppmv, and 2,000 ppmv exposure tests. These alarms were seen after less than 16 hours of exposure, though the detectors were able to be reset in a neutral atmosphere. One detector reported an error after an overnight exposure during the ongoing 2,000 ppmv exposure tests and were not able to be reset.

Models from two manufacturers were removed from the exposure chamber after two days and tested. Two devices did not respond to 10% LEL. The remaining units responded to both 10% and 25% LEL.

Status

This project is complete. A Final Report was issued in April 2021.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Hydrogen Working Group

The goal of this project is to develop and facilitate a focused Working Group of utilities that want to establish a comprehensive strategy for hydrogen blending into their systems. A workshop was held in to identify needs and develop a research/project roadmap.

Project Description

Advancing hydrogen as a viable energy-storage strategy and fuel is integral to meeting aggressive renewable energy goals and emissions reductions. Leveraging the natural gas infrastructure will be critical to achieving these objectives. However, understanding the consequences of mixing hydrogen with natural gas throughout the North American natural gas distribution system is important for maintaining a safe and reliable network.

For successful implementation of blending hydrogen into the natural gas system, key issues must be addressed that include impacts to: compliance, safety, integrity, consumers, end users, and the environment. While there have been a handful of studies investigating the introduction of hydrogen into natural gas pipelines, many of these have been special projects driven by individual companies or organizations. A collaborative and concerted effort is needed to drive the hydrogen market to scale and make it a viable opportunity for natural gas system operators.

For this project, a Working Group was formed to discuss a holistic technical strategy for hydrogen incorporation into the natural gas system inclusive of best practices, lessons learned, end-use appliance issues, generation, blending practices, regulatory concerns, and the continual collection/review/summary of published papers and research on hydrogen blending.

A workshop was held in 2020 to identify needs and develop a research/project roadmap that outlines the elements needed for successful implementation of hydrogen blending into natural gas pipelines. Several projects have been put in place.

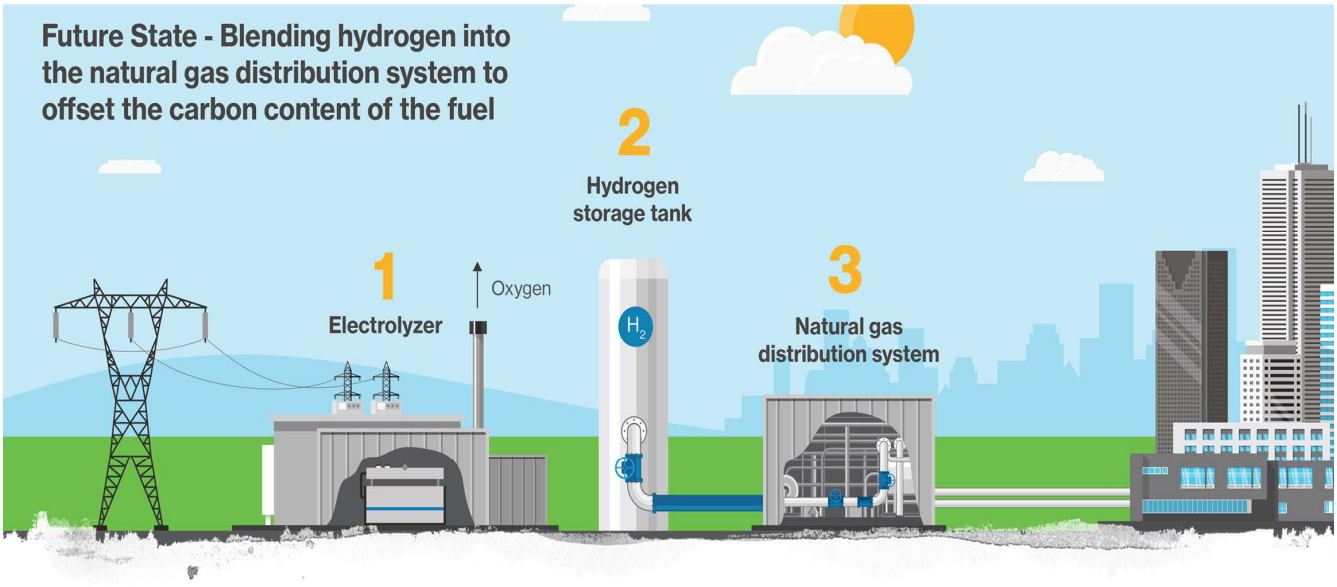
Deliverables

This project will produce the following deliverables:

- Final Report documenting the findings from a workshop
- Roadmap,
- Hydrogen information site.

Benefits

Adding hydrogen to natural gas can significantly reduce greenhouse gas emissions from gas use and will play a key role in the path to de-carbonization. However, unlike other fuels (e.g., biomethane) that have



injected into natural gas pipelines, hydrogen can have potential impacts to infrastructure and end-use applications. Limited research has been performed at scale to assess these impacts. A Working Group focused on hydrogen allows operators to share experiences, current efforts, and streamline the process for identifying and addressing technical gaps and other barriers to implementing hydrogen.

Technical Concept & Approach

Activities of the Working Group include an initial workshop to memorialize challenges and goals, map a strategic plan at the utility level, and prioritize next steps for developments of research projects/programs, position papers, and other studies.

The project will leverage practical knowledge of the members. A goal will be to lay out a general strategy and define successful implementation of the integration of hydrogen as a storage strategy and fuel source.

The project team will also develop a web-based library of information through literature collection and a proactive interview process with industry-leading operators in hydrogen blending. This will provide a constantly refreshed source of information on hydrogen and use in the natural gas network.

Results

A workshop was held in July 2020 to help develop the research roadmap for enabling hydrogen injection into pipelines. At the workshop, information was provided on a variety of current projects evaluating the impacts of hydrogen on the gas infrastructure and end-use applications.

The workshop provided information on vintage steels and welds. Key factors to consider include:

- Cracking and fatigue susceptibility of low-toughness, older steels that have higher sulphur and phosphorous levels
- Dynamic shock resistance (e.g., third-party damage)
- Engineering Critical Assessment (ECA) considerations
- Weld considerations, such as historic acetylene welds of lower quality
- Cleanliness of the steel
- Leak-vs.-rupture considerations
- Short- vs. mid- and long-term integrity considerations
- Operations and procedure adjustments, and
- Cut points on when it makes more sense to replace pipe and use modern materials and modern standards (e.g., ASME B31.12-2019 Hydrogen Piping and Pipelines) to transport hydrogen blends.

Priorities identified during the workshop were developed into high-level project ideas that were then converted to more specific project outlines with objectives and deliverables. A consolidated R&D Roadmap with prioritized projects and expected durations for each was assembled.

In spring 2021, prioritized projects were presented:

- Gap Identification Between Hydrogen and Natural Gas Standards
- Hydrogen Impact on Meters and Regulators
- Odor Masking and Odorant Fade in Hydrogen Blends, and
- Assessing Performance Impacts and Leak Rates of Hydrogen Blends on System Components.

A draft of the hydrogen web-based library and the user interface was presented for discussion among project sponsors. New areas of concern, such as customer billing having hydrogen-methane blends in the system and stratification of gas during laminar flow conditions, were presented by sponsors during the monthly meetings.

Status

The project team is obtaining materials that conform the hydrogen library.

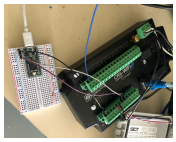
The project team is reviewing research needs and priorities of the working group and discussing potential new ideas.

Researchers are identifying projects to propose in the next OTD meeting according to the R&D Roadmap and the latest needs from sponsors and other external efforts in hydrogen blending.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Develop Remote Sensing and Leak-Detection Platform with Multiple Sensors



Efforts are under way to improve and deploy additional instances of a defensive pipeline right-of-way (ROW) monitoring system based on stationary sensors mounted on and near the pipeline. Sensor data from multiple locations along the pipe is wirelessly forwarded to a central location for processing.

Project Description

Activity (such as excavation) in the pipeline right-of-way (ROW) can have unplanned consequences, including damage causing gas leakage, greenhouse gas emissions, and disruption of energy delivery. In this project, research is being conducted to improve and deploy additional instances of a defensive pipeline ROW monitoring system based on stationary sensors mounted on and near the pipeline.

The research concept involves sensor data from multiple locations along the pipe being wirelessly forwarded to a central location for processing. Analytics at the central location correlates data from multiple sensors to rapidly alert operators to events occurring in the ROW.

Deliverables

One prototype system is currently deployed. The project seeks to deploy at least one additional instance with improved field hardware and machine-learning analytics incorporated.

Deliverables include deployment and testing of improved systems on utility sites.

Benefits

The anticipated benefits of a ROW monitoring system are real-time information on events before they develop into incidents. This will allow pro-active response to developing situations such as construction activity near the ROW that has not yet infringed on the pipeline. Additional benefits would accrue if the ROW monitor sensors were co-located with other utility installations.

Combining a pressure-monitor station, regulator station, rectifier, or cathodic-protection test point with the ROW monitor system will allow the capture of operational data as well. This will provide a cost advantage over a monitor system intended solely for damage prevention by eliminating personnel visits for routine operational data.

Technical Concept & Approach

This project includes the following tasks:

- **Technology Review**

  The purpose of this task is to provide the project stakeholders a thorough review of the current state of the technology and the path forward.

- **Hardware Improvements**

  While there are no expected fundamental changes to the sensors, implementation details must be addressed. The current prototype system is functional but needs to be field hardened. Several sub-systems are to be made smaller and could function at lower power consumption. The connectors and cabling need to be upgraded from research to industrial specification parts. The overall size of the field equipment needs to be reduced, easing the effort and cost of the installation.

  The most significant modifications were to the on-pipe vibration sensors and their support electronics. These are piezoelectric sensors directly in contact with the pipe and have demonstrated the ability to detect impacts near the pipeline. The ease of sensor application and the reliability of the support electronics was also upgraded. The methods of

Sensors on pipe and in soil.

installing sensors on the pipe were modified to minimize the time required. Prior methods re quired coating removal and significant surface preparation.

- **Data Management and Analytics**

  A basic function of the ROW monitor system is to capture diverse data from sensors in the field and correlate it to identify threats to pipeline integrity. Data management also addresses the storage and retrieval of information. The data architecture provides short- and long-term storage capabilities for quick response to current activity and archival baseline data for trend analysis.

  The set of sensors are on the pipe itself (vibration sensors, a longitudinal strain gage, and a wire for the current density measurement) and in the soil nearby (a steel coupon that is connected to the pipe wire through a measurement shunt, a geophone to measure soil vibration, and a combined probe for soil moisture and temperature).

- **Improvements to User Interface**

  Live data from the prototype site and from a test installation will be used to test improvements. The improved version of the user interface will be demonstrated.

- **Deployment of System**

  Hardware improvements are being tested on buried piping. This allows performance comparison of the field-hardened versions of the equipment with the prototype system already in operation.

Another recommendation was to secure the system against lightning damage. Most modern instrumentation has some form of lightning protection built in. The system could pro-actively perform some shutdown operations to protect itself. The lightning occurrence data would also be useful in identifying nearby strikes that could damage cathodic protection systems and coatings.

Researchers are also adding microphones to the above-ground portion of the listening post to provide corroborating data when vibrations are sensed on the pipe by listening for heavy equipment. Likewise, they can provide further evidence of lightning activity.

Other improvements that have been proposed are to refresh or upgrade the data-logging instruments and supporting radio equipment.

Investigators are examining pin brazing as a means of installing sensors requiring metallic contact. Pin brazing uses a material that can join a stud to the pipe surface at a much lower temperature. This technique is recognized by utilities and allowed as a procedure on their systems. The surface cleaning and preparation for brazing is less stringent than that required for adhesive bonding.

Results

Researchers cataloged and reviewed the standards that exist for sensor data. These standards were reviewed to develop a gap analysis between the standards for sensors and the devices and data being utilized in this project.

A lightning detection sensor was investigated to monitor lightning activity near the sensor station. This can aid in root-cause analysis of a failure; lightning damage often goes undetected or misdiagnosed. The sensor was interfaced with a development platform to monitor for lightning and test the reliability and accuracy of the sensor.

Preliminary machine-learning models were trained to classify a handful of common environmental noises that may pose a threat to the pipeline (e.g., jackhammers, engine idling, etc.). Further research needs to be done in testing of the model in real-life scenarios. Interface libraries for the gas and lightning sensor were developed, tested, and are operating as intended.

The project team created Amazon Web Services Lambda functions to transmit sensor data to the geographic information system. These functions rely on code written by the team as well as a third-party library that facilitates the retrieval and processing of the sensor data.

Status

The project team continues to work with sponsors to identify a site or sites where the ROW monitoring system may be deployed.

Development on the sub-processor hardware and software is progressing into the advanced laboratory testing stage.

Further testing is in progress to interface the sub-processors with the system and transmit the data from the Cloud.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Validation of Remote-Sensing Leak-Detection Technologies Under Realistic Conditions

Research is being conducted to advance an unmanned aerial system with mounted remote-sensing technologies for identifying right-of-way integrity threats and detecting natural gas leaks under operational conditions.

Project Description

The importance of monitoring the natural gas pipeline system has driven recent technology development, specifically using remote-sensing instruments on drones. Drones can be deployed to survey inaccessible pipeline areas with low impact to the environment or disruption to the public.

While testing facilities can offer control, they do not produce real-world, operational conditions that can include interferences, such as leaks from adjacent infrastructure, buildings, noise walls, and varied terrain or land cover. In this project, senor-mounted drones were tested in "real-world" controlled conditions to obtain a probabilistic understanding of instrument performance and reduce barriers to implementation.

Deliverables

Deliverables include a real-world, operational validation test framework for drone-mounted technologies, results obtained from using that framework to field validate drone-mounted integrity and methane detection sensors, and information from an evaluation of uncertainty.

Benefits

Use of the most advanced technologies for natural gas leak detection can reduce overall environmental impacts created by methane releases and reduce risks associated with undetected natural gas leaks.

There is a unique co-benefit to leak sensing from drones, which is the ability to also monitor for right-of-way integrity threats. In particular, drones with appropriately validated sensors can also be used to identify encroachment or unauthorized third-party excavation.

Data developed through this project will aid the further validation and adoption of new leak-detection technologies by obtaining a clearer understanding of uncertainties surrounding deployment of sensors at actual facilities.

Operators can use the validated technologies to decrease product loss and increase safety by lowering risk of failure through early identification of leaks and integrity threats (potentially with the same platform); reduce incidents due to leaks or other mishaps, such as third-party excavation damage; and decrease environmental impact.

Technical Concept & Approach

Even with the expansive literature and guidance available today, approaches for performance testing of leak-detection sensors and imaging systems are rapidly becoming outdated as new instruments possess ever-increasing amounts of complexity. By focusing performance testing on the *methods* used (rather than individual sensors), it is possible to achieve a more effective and standardized framework for validation.

For this project, a research team is engaging end users and a vendor to 1) develop an operational validation test framework focused on operating field sites within the pipeline network, 2) use a single-technology vendor to evaluate the framework, and 3) model sensor performance in a manner that can be fed into higher-level risk models.

Investigators developed a framework for standardized sensor specifications, test procedures, and instrument certification. Researchers are also conducting real-world validation of sensors with long-term performance tests of remote leak-monitoring technologies at remote/rural metering and regulating stations.

Results

In 2020, the project team paired a methane-detection system and camera with a drone system. A preliminary field trial of the drone platform was performed to evaluate flight stability after integration with the methane sensor and optical sensors. Additionally, the ability of the drone platform to capture aerial images was put to the test in the trial.

In 2021, the project team participated in controlled real-world leak testing at a transmission pipeline sites. Two methods were used for investigation: straight-line paths and box methods. In straight-line paths, the drone made straight passes directly over and a measured distance off-axis of the leak source. For box methods, the drone would fly a square pattern over a determined area to survey a potential leak source. Both methods were performed at altitudes of two, three, and five meters, and six passes were made for each method.

At one site, variable-terrain testing took place near a gas production area. Some elevated background was detected in surveys both with the drone and a handheld combustible gas indicator (CGI). For surveying over a water source, a container was filled with water from a nearby stagnant water source. The drone was instructed to make a box pattern around the water source to evaluate detection capabilities. Observations from testing showed dense fog and high moisture in the air carried methane from surrounding sources and saturated both the drone sensor and CGI. Flight during fog is also problematic as regulations and visibility may not permit flight.

Runs and passes were grouped to improve the detection probability. When grouping passes, if any of the individual runs resulted in a detection, the entire group would have a positive detection. By grouping four passes, the detection probability at various leak rates was at 100% for both the line tests and box tests. Additionally, the leak-detection performance was evaluated at different drone altitudes. The hypothesis is that methane plumes have a tendency to stay close to the ground as it is affected by the wind. Thus, flying at a low altitude presents the best chance to transect the plume irrespective of wind speed. However, that was not necessarily the case in this testing. By comparing the detection probability against different altitudes, it was found that there was no obvious benefit of flying at a lower altitude for the line tests. Additionally, the box test achieved perfect performance at every height flown, so there was no way to determine differences by flying altitude.

The real-world field testing was conducted over three days. Researchers determined that the box pattern can achieve better performance than the normal line pattern.

For the threat-detection component of the project, investigators collected several videos with staged integrity threats for analysis.

In April 2021, the project team completed a controlled blind field test using the testing framework developed in this project. For this test, researchers used a total of 15 controlled leak sources. Instead of the operators flying in a search-and-pinpoint strategy which was done in other studies, the drone was specified to fly in a back-and-forth route parallel to the pipeline right-of-way in order to mimic an aircraft-based leak survey on long stretches of transmission pipelines.

Status

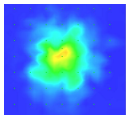
A Final Report is in preparation.

The project team is still actively engaging in discussions with potential partner utilities to identify the final site for testing. The final request to partner utilities will be for sites that are hard to access, such as canyons, wetlands, or hills.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Gas Dispersion Modeling for Venting Natural Gas from Structures



The objective of this project is to develop a best practice on how to properly vent accumulated natural gas from a building through both physical testing using a built structure and computational fluid dynamics modeling.

Project Description

In recent years, Fire & Risk Alliance (FRA) performed two natural-gas modeling efforts for utility customers. The focus of these projects was on methane gas dispersion in residential buildings. The first project provided guidance on the placement of residential methane detectors (RMDs) using a small one-room test facility simulating a city kitchen. After this initial study, FRA performed an additional placement study using a residential home custom built for the project.

The objective of this project is for FRA and researchers to develop a best practice on how to properly vent accumulated natural gas from a building through both physical testing using a built structure and computational fluid dynamics modeling.

Researchers will map the dispersion and ensuing ventilation of natural gas from within a residential structure for several different scenarios. This information will improve the ability of first responders or utility personnel to employ safe and proven techniques to carefully ventilate natural gas down to safe levels.

Deliverable

The deliverables for this project include:

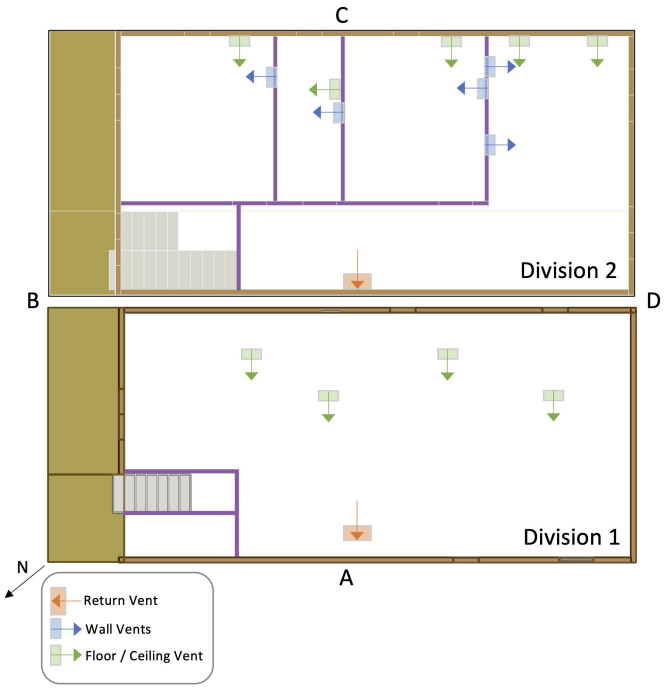
- A Best Practices manual for first responders and utility workers
- Video and still images from computer modeling, and
- A Final Report with conclusions.

Benefits

While rare, natural gas leaks can be dangerous and may result in serious consequences if undetected. This project focuses on improving the safety of natural gas systems.

Technical Concept & Approach

Test-case scenarios were requested from the project sponsors to determine the critical needs for onsite



Left: FRA custom-built home for gas dispersion studies. Right: Divisional layouts of the structure.

testing. An extensive literature review was performed to help guide the ventilation study.

Testing was conducted at the FRA gas testing house in Damascus, MD. It is a test enclosure with external dimensions measuring nominally 20 feet by 40 feet by 20 feet that is constructed of dimensional lumber to simulate a large residential structure. The house contains standard insulation in the external walls and attic.

Experimental measurements were recorded with a data-acquisition system using a custom graphic user interface developed to control and monitor the system during the experiment. Measurements include methane concentration, relative humidity, and air velocities. The two different types of methane sensors were placed throughout the enclosure to monitor methane spread and concentration. Nominally, 60 separate combustible gas sensors were used.

Different ventilation approaches were explored to determine the optimal ventilation strategies and map the corresponding decrease in gas concentrations throughout the structure.

A modeling effort was conducted to validate the measurements and to simulate the effect of ventilation on the accumulated concentration of natural gas within the test structure. The modeling also expands on the experimental program to include scenarios that could not be fully tested.

A a Best Practices manual will be developed detailing how first responders can safely vent natural gas from a variety of residential leak scenarios.

Results

In 2021, FRA completed testing and provided a Final Report. The objective was to characterize the ventilation blower, identify optimal fan placement with respect to the doorway, and baseline ventilation testing to characterize systems within the testing facility.

Among the conclusions made were:

- The lack of partitions of an open floor plan allows for much more efficient ventilation when compared to the baseline test.
- Elevating the blower leads to improved ventilation. (Angling the blower has a detrimental impact on ventilation performance.)
- Moving the blower further from the doorway led to a slight ventilation improvement.
- Locating the blower inside of the compartment, blowing out provided a slight performance improvement compared to the configuration locating the blower outside, blowing in.

"The dispersion modeling and physical testing of this project will have immediate benefit to operators by combining good science with practical application to enhance of our emergency-response procedures with the best process to vent natural gas from structures."

- Richard J. Trieste, Jr.
Department Manager
Research, Development, and Demonstration
Consolidated Edison Company of New York

- Applying ventilation to a compartment experiencing an active leak had a positive impact in all cases.
- In all cases, it is most effective to ventilate through an opening closest to the location of the leak. If unable to locate the blower close to the location of the leak, it is most effective to ventilate by creating an outward draft by placing the blower inside of the structure, blowing out, or by introducing a secondary opening downstream of the blower.
- Secondary openings have the most influence on improving ventilation performance, especially for smaller floor plans.
- Active HVAC negatively impacts the efficiency of ventilation by re-circulating and distributing the gas while working against the air flow of the ventilation.
- Applying ventilation to a compartment experiencing an active leak reduced the hazard level of the compartment with no additional intervention.
- The lack of partitions of an open floor plan allows for much more efficient ventilation when compared to a closed floor plan.

A total of 81 tests were conducted, which are discussed in a report issued in October 2021.

Status

The project team is incorporating FRA research into a Best Practices document.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Characterizing Methane Emissions from Purging Activities

Researchers are developing a method to quantify the volume of natural gas emitted during the commissioning of a pipeline. This method will be validated in preparation for field studies.

Project Description

Utilities are increasingly interested in ways to measure, report, and reduce methane emissions produced from a natural gas distribution system. Although distribution companies typically report lower methane emissions compared to other areas in the natural gas value chain, there is still a need to continue reducing these totals.

A breakdown of methane emissions across the natural gas value chain determined emissions rates and leak probabilities on a number of asset types, but one such area yet to be characterized in greater detail is a purge event. Typically, emissions from such events are determined from engineering calculations based on volume, temperature, and system pressure drop. Further investigation into this area would help validate the current methodology and provide a technology resource capable of measuring these volumetric quantities of methane emissions.

This project involves an investigation into methodologies needed to quantify emissions from gas purging with the intention of ultimately providing solutions to lower overall methane emissions in future inventories. This can be achieved with the help of a high-velocity flow meter and methane-concentration detection. This method will be validated in preparation for field studies.

It is envisioned that the knowledge gained from this project could be applied to emergency blowdowns at a later stage.

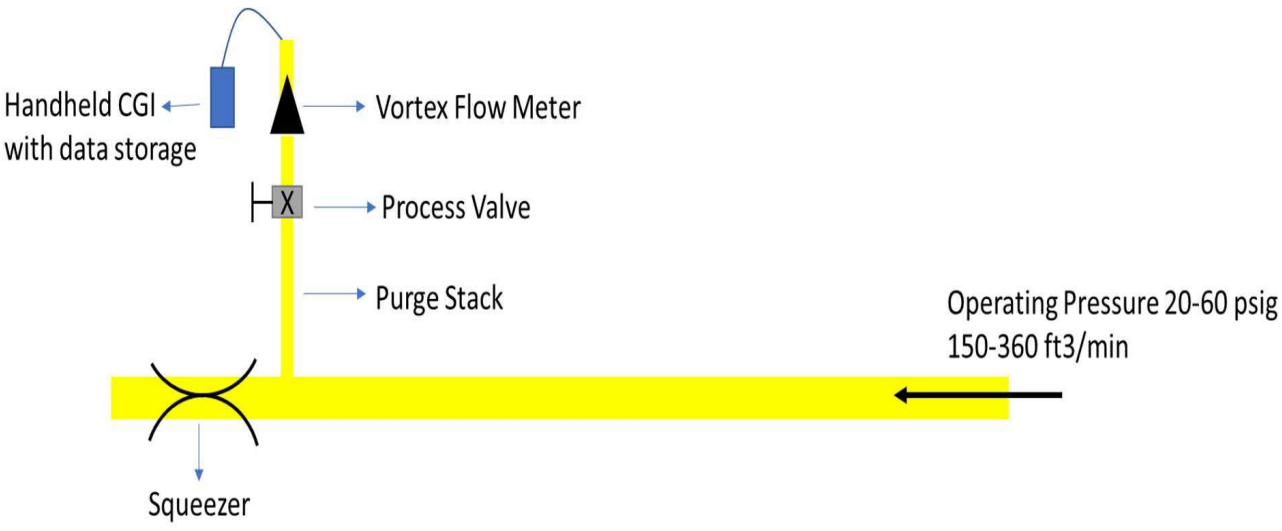
Deliverable

If successful, this project will deliver a means to quantify volumetric quantities of methane emissions produced from a pipeline purge. Researchers will be prepared to use this technology to conduct field studies in a follow-on project phase.

Benefits

By developing a better understanding of pipeline purges, natural gas distribution companies can evaluate the impact of this emissions source. Technologies and methodologies to reduce natural gas emissions during a purge activity can be explored with an eye towards decreasing methane emissions further in the future.

With improved knowledge of the volumetric quantities emitted during a purge, researchers can study methods to remediate this emission source. This effort could result in potentially lower methane emissions among distribution companies.



General process description.

Technical Concept & Approach

The project team will review commercially available technologies and develop a feasible approach to measure volumetric quantities of natural gas emitted during a purge. The team will then validate the proposed methodology via testing. If successful, a Phase 2 project would focus on executing project sponsor field trials of the methodology.

Project scoping includes efforts to understand which key technical needs (e.g., pressure, flow rate, pipe material, and pipe diameter) are most applicable.

The project team performed a search of technologies available. Laboratory validations include simulating and measuring flows and gas mixtures that could be sustained during a purge.

Results

In 2020, researchers evaluated gas-sensing and flow-metering technology that could withstand gas flows during a purge. There are several options to quantify this amount of gas emitted during a purge, but they are designed under the pretense that the system must tolerate high flows from fully opened gas lines with operating pressures up to 60 psig. This is of note because the project team also had the opportunity to witness a live purge demonstration. During this demonstration, the flow was purposely constricted through a nearby valve. This observation led to some re-evaluations regarding system design.

There are three options in designing the purge flow meter. Due to the high flows experienced during a 20-60 psig purge, hydrocarbon gas-sensing options with high sampling frequencies are limited. However, the team identified an oxygen sensor that can withstand these flows and sample at a high enough frequency to capture changes in gas concentration from mixing during a purge. The team is also aware that some utilities may not be purging under full-flow conditions. If low flow purges are more common, more options for hydrocarbon sensors become available to the team.

With this general framework, the team has three possible paths to design the purge flow meter:

1. **Indirect Hydrocarbon Measurement**

   This design will install both an in-line oxygen gas sensor and a thermal mass flow meter. The main gas flow will be sent through the sensor and flow meter so that a volumetric flow rate is recorded with respect to the changing oxygen concentrations. This is advantageous because the system will directly capture gas concentration data and flow data without modifying the flow stream. This route is the simplest way to collect high-flow data and capture mixing of the gaseous species; however, the team acknowledges that this method indirectly measures the hydrocarbon content in the flow.

2. **Direct Measurement of Hydrocarbons**

   To directly measure the hydrocarbon content of the flow, the team must divert a slipstream from the main gas line or regulate the pressure down at the purge end to decrease the flow for analysis to accommodate the lower gas-velocity requirements for hydrocarbon sensors. By lowering the velocity of the flow in this scheme, the team can collect representative samples of the hydrocarbon concentration in the main gas flow over time. The gas flow will be sent through a thermal mass flow meter so that a volumetric flow rate is recorded.

3. **Low-Flow Purges**

   If this is found to be a more common method, the team can reevaluate the selection of the hydrocarbon sensor as it will more than likely be rated to handle lower flows. Then, mimicking the design in first option, the team could produce a system with direct hydrocarbon measurement.

Based on sponsor feedback, a direct method to measure hydrocarbon content in the gas flow was preferred. The team determined a new design to allow measurements and emissions calculations with new high-performing off-the-shelf CGIs. With this method, the project team can validate the method and data-collection process and sponsors would have the ability to determine emissions with a CGI and an accompanying flow meter in the field if desired.

In 2021, the research team moved ahead with assembling the flow meter and ordered an additional power supply. The flow meter is now capable of collecting data.

Status

The project team will troubleshoot data-acquisition and recording equipment, and utilize each device's programming capabilities.

A test matrix will be constructed after consultation with sponsors.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Laboratory Evaluation of Personal Gas Monitors

For this project, researchers conducted a testing program of commercially available personal gas monitors. Testing included performance evaluation at 5%, 10%, and 25% LEL of methane in air, possible interferences from commonly used household chemicals, and the impact of hydrogen blended into natural gas.

Project Description

The specific sensors used in personal gas monitors (PGMs) vary with each manufacturer, but, in general, are based on the same semiconductor micro-electro-chemical technology. Over time, these sensors are known to experience a slight drift and the electronics are adjusted accordingly to ensure appropriate response over the estimated device lifetime. Certain chemicals can also affect these detectors.

A *false negative* on a PGM is the absence of an alarm that improperly indicates methane is *not* present when methane *is* present. A *false positive* is an alarm when something other than methane is present. Confirming that an accurate response will occur even when the PGM is exposed to common household chemicals and/or hydrogen gas is critical if these devices are to be used by natural gas company employees for monitoring their safety.

For this project, researchers tested commercially available PGMs to evaluate 1) their performance at 5%, 10%, and 25% LEL (lower explosive limit) of methane in air, 2) possible interferences from commonly used household chemicals, and 3) the impact of hydrogen blended into natural gas with testing at 95% methane and 5% hydrogen.

Deliverables

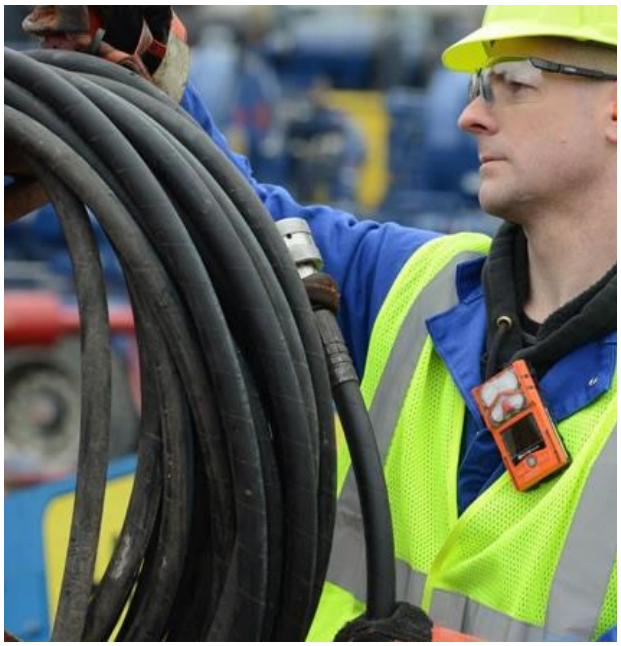
This project provides data on the responsiveness of five selected PGMs after exposure to different concentrations of methane, hydrogen blended into methane, and common household chemicals.

Benefits

PGMs are portable devices for users to wear on their belt or chest pocket to provide a warning to users in the field that increased levels of methane are present before combustible levels are reached.

These monitors are valuable safety tools for field employees at all stages of natural gas distribution. PGMs provide an accurate and stable early-warning system while on the job and improve safety for employees.

Having an accurate and stable early-warning system while on the job can improve safety for employees and prevent unfortunate events from occurring due to smell blindness, undetected gas leaks, or other chemicals interfering with the sensor.



Technical Concept & Approach

Initially, the research team led a discussion with sponsors during the kick-off meeting to select the PGMs to test and finalize the test list. Up to five manufacturers were tested in triplicate.

A series of tests were conducted to evaluate PGM performance with three levels of methane plus a methane/hydrogen blend (95/5). Additional testing will be performed with a standard list of household chemicals.

Results

Five brands of PGMs were tested in triplicate in this study. One device contained only a combustible gas sensor, although the model can be configured for up to four gases. The other four devices have four sensors: carbon monoxide, hydrogen sulfide (H2S), %LEL, and oxygen. The data recorded for these monitors was the numerical reading plus a determination of pass or fail dependent on if the device made an audible alarm.

The five tests were:

- **Test 1:** Verification of each PGM's response to methane and propane in air at 25%, 10%, and 5% LEL.
- **Test 2:** Testing for false positives or interference using a standard list of household chemicals.
- **Test 3:** Testing for hydrogen impact on detector response at three levels (5%, 10%, and 25%). This test gas was 95% methane/5% hydrogen and was diluted to reflect LEL levels of methane only, irrespective of the presence of hydrogen.
- **Test 4:** Testing for hydrogen impact on detector response at three levels (5%, 10%, and 25%). This test gas was 95% methane/5% hydrogen and diluted to reflect total LEL including hydrogen.
- **Test 5:** Signal and sound level testing across four available construction media (e.g., drywall or concrete block). The acceptance criteria for this study is defined by the detectors emittance of an audible alarm when exposed to the tested chemicals and materials. A field employee should not have to visually monitor a display to know they are safe. When potential danger arises in the field, the PGM should give an audible, visual (blinking lights), and physical (vibrations) alarm to alert the user.

All devices alarmed properly when exposed to methane and propane at the 25% LEL methane in air concentrations. At 10% LEL concentrations, the response was

mixed with one not responding to methane and three not responding to propane with audible alarms. However, these tests also show that some common household chemicals produce a false alarm in the detectors. The household chemicals that affect the PGMs are ethanol-based solvents, acetone, and duster spray.

Hydrogen-blended methane gas has an impact on these monitors as well. False alarms indicating carbon monoxide were produced at multiple %LEL levels even when the %LEL alarm also sounded. PGMs with multiple sensors may not be the best selection for natural gas blended with hydrogen.

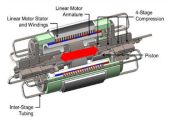
Status

This project was completed with a Final Report issued in June 2021.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Methane Mitigation Using Linear Motor Leak Recovery Compressor



Research is under way to design, build, and test a novel, low-cost, leak recovery compressor to capture a wide variety of leaks across the natural gas value chain, including leaks from reciprocating compressors and pneumatic controllers.

Project Description

The U.S. Department of Energy is actively funding efforts aimed at reducing methane emissions from compressors and pneumatic controllers through the use of low-cost methods that can be used at newly installed locations or retrofit onto existing equipment. The linear motor leak recovery compressor will do just that by tapping into the methane vent lines installed on compressors, pneumatic controllers, and other common leak sources, and compressing the leaked methane back into the pipeline.

This simple solution enables 100% of these methane emissions to be captured and recovered without any impact on the performance or operation of the original equipment.

The linear motor leak recovery compressor's low cost and nearly-zero maintenance allows for use across the high-pressure transmission and storage sector, as well as in upstream gathering and processing facilities.

The primary challenge preventing the capture and mitigation of these leaks is the absence of a suitably engineered and priced solution. The linear motor compressor improves on the traditional reciprocating compressor by eliminating all but a single primary moving part, even when multiple stages of compression are required for high discharge pressures.

The design has multiple stages of compression directly powered by a reciprocating linear motor in place of the normal crank assembly. The precise motor controls allow the piston to rapidly move back and forth without striking the ends of the cylinders. The speed, frequency, and stroke length of linear motor compressor can all be controlled to fine tune the flow of the system. The directly powered linear motor can also start up and shut down instantly, enabling the unit to compress to full discharge pressure from a dead stop. This capability also enables the flow to be infinitely adjusted from zero to the full design flow.

Because of the unique flexibility of this technology, the compressor can also be used to recover emissions from planned events such as blowdowns that are required as regular maintenance. These planned events are frequently the single largest source of emissions at a site and can be avoided if the gas trapped in the equipment is compressed downstream rather than vented to the atmosphere.

To date, the project team has tested and refined the linear motor compressor. This project will validate the effectiveness of the technology in a variety of relevant environments to identify and quantify the wide-ranging applications for its use. Furthermore, the leak recovery compressor will be designed such that it can be installed at a commercial scale across the natural gas sector in a manner that does not require new permits to be issued by the Environmental Protection Agency.

Deliverables

The project team will submit quarterly progress reports to sponsors. A complete prototype will also be built and tested. Data and results from this testing will be summarized and provided to members.

Benefits

Reducing and capturing methane emissions are important objectives in the optimization of the U.S. natural gas value chain because it makes it safer to operate natural gas equipment, reduces waste of a valuable natural resource, and increases the sales volume of natural gas.

This simple approach can be applied to compressor valve packing and seals, pneumatic controllers, and blowdown events. By recovering methane from a variety of sources using the leak recovery compressor, the natural gas industry can significantly improve the safety and efficiency of the natural gas infrastructure.

Technical Concept & Approach

This research effort includes a full detailed development and validation of a pilot-scale leak recovery compressor using a patented linear motor drive. The project will be initiated with the simulation and modeling of the linear compressor for the leak recovery application. The compressor will then be fabricated, assembled, and tested to validate the performance and identify any design issues. A detailed design of the compressor will be developed that includes the full leak recovery system, including the balance of plant components and necessary modifications to the compressor design. Lastly, the full leak recovery system will be fabricated and extensively pilot-tested to verify that the performance meets the design requirements and that the full system is ready for field deployment at a controlled test site.

Key components (e.g., valves, seals, and motors) will be designed and integrated into the compressor solid models and undergo extensive thermal and structural finite element analysis.

A test apparatus will be used to validate and improve the linear motor compressor performance and sub-assembly performance. Results from this testing will be used to improve the assumptions in the simulation.

The project team will verify operation in a relevant environment that matches real-world conditions for the leak recovery compressor, including verifying that the controls and safety features are working properly.

Results

In 2021, investigators at the University of Texas at Austin created a simulation of the compressor stages and explored variations in many physical parameters to down-select the preferred motor and compressor design characteristics and to verify that they meet the performance requirements across a broad range of simulated operating conditions. After evaluating many variations in design and operating parameters, appropriate design parameters were chosen for piston areas, stroke lengths, and check valve sizes that produce the right outlet pressures and flows using assumed inlet pressures and stroke frequencies.

Simulations were conducted to predict dynamic pressures and temperatures in each stage of compression. These simulations demonstrated that the compressor should be able to deliver 50-60 standard cubic feet per minute of flow from an atmospheric inlet pressure to a 1,500-psi discharge necessary for capturing leaked methane and returning it to a midstream pipeline.

This simulation tool was also used to evaluate whether a three-stage compressor could be used instead of a four-stage system. Results showed that the project goals could be met with a three-stage compressor, so that is the configuration that is being used in the ongoing hardware design efforts. A three-stage system has some operational advantages (higher reliability, longer life) if the number of parts (pistons, seals, valves, etc.) can be reduced and the thermal loads can be managed better (e.g., reduced heat exchanger sizes).

A test loop that includes intercoolers, filtration, and instrumentation is being modified for the three-stage compressor design. The team also identified suitable coalescing filters. In addition, the team is making efforts to identify a knockout filter for the compressor suction that will cause any oil or debris from pipeline leaks to be filtered before they reach the leak-recovery compressor.

Each stage of compression will include pressure transducers and temperature sensors to fully characterize the performance of the system.

A detailed economic and business case model was developed. The analysis was done considering a standalone business operation. Several product scenarios were considered.

Status

Researchers are finalizing the three-stage compressor design and the control system based on the output of the revised and refined system simulation. The research team will also finalize the specification of components (valves, intercoolers, etc.) and select suppliers. The design of the motor frame and compressor ends will be completed and fabrication drawings will be prepared.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Residential Methane Detectors (RMDs) – Test Response to Natural Gas/Hydrogen Blends

Using the protocols established in the earlier phases of the Residential Methane Detector Program, RMDs are being tested at various methane/hydrogen blends in a controlled laboratory setting to determine how their effectiveness at detecting leaking gas may change and at what alarm levels.

Project Description

The blending of hydrogen into natural gas pipelines presents an opportunity for the gas industry to reduce greenhouse gas emissions from gas use and will play a key role in the path to de-carbonization. As the gas composition of fuel sources changes, impact to the infrastructure as well as to the customer are being evaluated. This includes evaluations of devices used for residential methane detection.

In an OTD project 1.14.g, extensive testing was conducted on Residential Methane Detectors (RMDs). Additional tests were conducted on international devices from Japan and Europe. The specific sensors used in RMDs vary with each manufacturer but in general are based on the same scientific semiconductor technology. Over time, these sensors are known to experience a slight drift and the electronics are adjusted accordingly to ensure appropriate response over the estimated device lifetime.

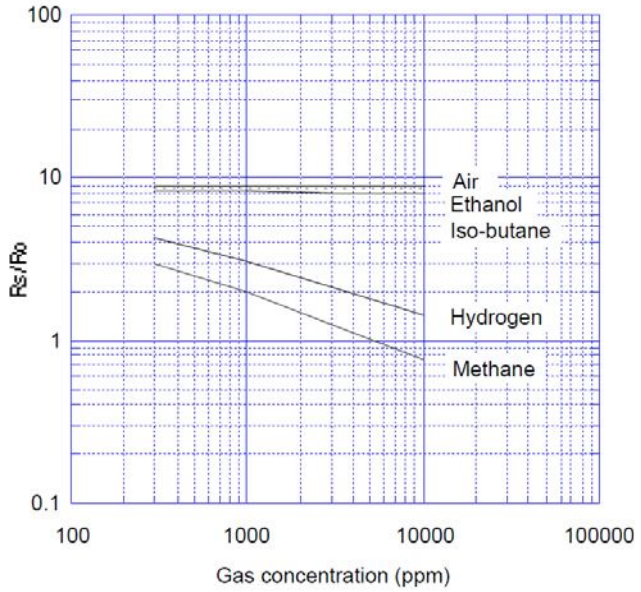
Currently, the impact of the presence of hydrogen on the alarm level and performance of an RMD is not known. Technical data sheets from some of the largest suppliers of sensors in RMDs indicate that hydrogen will induce a response along with methane. Other sensors exhibit similar responses.

Using protocols established in earlier phases of the RMD program, in this project RMDs are being tested at various methane/hydrogen blends in a controlled laboratory setting to determine their effectiveness at detecting leaking gas and at what alarm levels.

Deliverables

This project will provide data on the responsiveness of four selected RMDs after exposure to five different mixtures of hydrogen blended with methane. Researchers will determine the blend concentration at which the tested RMDs respond with an alarm.

RMDs are being tested at various methane/hydrogen blends in a controlled laboratory setting.



Methane and hydrogen response for a selected gas sensor

The final test set will determine the point at which each detector begins to alarm with each gas blend.

Benefits

The natural gas industry is committed to delivering a safe and reliable product to its customers. The use of odorant in natural gas distribution systems is the primary means for the general public to be aware of a potential natural gas leak. RMDs supplement this by acting as early-warning systems to improve safety and prevent unfortunate events due to unreported or undetected gas leaks. However, what is unknown is what is being tested in this program – the impact of hydrogen/methane blends on the performance and alarm level of RMDs designed for detecting methane from leaking natural gas.

Technical Concept & Approach

This project is designed to answer the hydrogen responsiveness question by performing a series of tests on PGMs with differing levels of hydrogen blended with methane.

Products from three manufacturers were recommended to be tested. A total of five detectors will be selected by the sponsors.

The existing RMD test chamber(s) will be suitable for this series of tests. A series of tests will be conducted to evaluate RMD performance upon exposure to blends of gas containing hydrogen and methane. All detectors will be pre-qualified at 10% and 25% methane in air, after which the detectors will be exposed to each of the gas mixtures at the calculated 10% and 25% in air concentrations. Each test will be conducted in triplicate.

Results

In 2020, six different RMDs were selected for testing. A 220v power requirement issue with one of the devices was resolved by purchase of step-up transformers. The certified test gases were also purchased and a hydrogen safety sensor was selected.

In 2021, five out of six RMDs selected were tested at 10% and 25% LEL methane in air. These five brands all passed the 25% LEL methane in air test. Four out of the five brands were tested passed the 10% LEL methane in air test.

Researchers conducted testing with the 5% hydrogen/95% methane blend and 10% hydrogen/90% methane blends on three brands.

Status

Researchers are completing testing of RMDs in hydrogen/methane blends.

A Final Report is being drafted for sponsor review.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Evaluation of Advanced Technology for Investigating a Gas-Filled Structure

Researchers are exploring the applicability of advanced technologies such as handheld laser methane detectors, optical gas imagers, and robot-mounted technologies for investigating potential gas-filled structures while keeping first responders at a safer distance.

Project Description

Some utilities have adopted the use of new technologies to investigate a gas-filled structure and have established unofficial procedures for instrument use. However, there are several unknowns that currently limit consistent deployment of these technologies. These include:

- Impact of different window types on detection capabilities of handheld laser methane detectors and optical gas-imaging cameras
- Locations of other detection points (such as eaves or vents) on the structure where technologies can be used, and
- Other factors that may limit performance of advanced technologies, such as distance, wind speed, wind direction, and obstructions.

The American Gas Association (AGA) established a task force to focus on issues pertaining to gas-filled occupancies (GFOs). Some of the ideas discussed and background information collected through the task force led to the areas of research being conducted in this project.

Previously, investigators conducted various evaluations of technologies. In project 7.18.f, *Evaluation of Point and Shoot Methane Detection Technologies,* there is an ongoing evaluation of handheld laser methane detectors. Researchers performed a preliminary investigation of the impacts of uncoated single- and double-paned windows. There was no impact of these types of windows on detection; however, many new energy-efficient windows have coatings that block UV light, which happens to be the wavelength of the handheld laser methane detectors. Therefore, more information is needed to determine how the abilities and limitations of handheld laser methane detectors.

Researchers also evaluated the use of a tactical robot to investigate gas leaks and factors that may impact the effectiveness. In project 7.18.c, *Robot for Remote Methane Detection,* investigators evaluated the navigation and communication abilities of an intrinsically safe robot. The robot was observed in tasks such as climbing stairs, opening doors, lifting objects, and in preliminary leak investigation while holding a point-and-shoot methane-detection device. Technical aspects of the robot were also investigated to establish communication and operational frequency strength between the operator and robot.

Another relevant OTD project is 7.16.b *Evaluate Gas Imaging Technologies for LDC Applications*. In this project, researchers evaluated optical gas-imaging equipment under leak-detection scenarios. However, the technologies were not evaluated for use in a gas-filled occupancy scenario. The lessons learned evaluating those technologies will translate to this project.

The goal project is to explore the applicability of advanced technologies such as handheld laser methane detectors, optical gas imagers, and robot-mounted technologies for investigating potential gas-filled structures while keeping first responders at a safer distance.

Deliverables

- A public White Paper/fact sheet detailing the use of handheld laser methane detectors and optical gas imaging in a gas-filled occupancy scenario
- A Public White Paper/fact sheet detailing the use of robots for a gas-filled occupancy scenario, and
- A Final Report.

Evaluation of handheld laser methane detectors for an earlier project.

"These technologies will alert our first responders of a high-risk situation so that they can take appropriate safety measures before entering a gas-filled structure."

- Prajwal Deshpande
Director of Safety Technology
NiSource

Benefits

Reports of gas-filled structures or gas-filled occupancies are encountered frequently by first responders and utility workers. New technologies for identifying leaks have been rapidly introduced to the market in recent years. Some of those technologies (e.g., handheld laser-based methane detectors, robots, and optical gas-imaging cameras) have the potential to be used to investigate gas-filled occupancies at a safer distance.

Technical Concept & Approach

This project has the following objectives:

1. Coordinate with sponsors and the AGA Gas-Filled Occupancy Task Force to determine appropriate test scenarios
2. Develop appropriate procedures for the specific gas-filled occupancy use case, focused on what can be done prior to entering
3. Interact with instrument vendors to ensure proper use-case deployment
4. Perform testing at a controlled leak-training facility
5. Perform testing during emergency-response training, and
6. Report on performance during use cases.

The project team will also use extensive field logistics required to complete the training facility access and use arrangements and first-responder action evaluation.

Researchers and a robotics company are making efforts to advance gas-detection capabilities. This may include but is not limited to upgrades to the mechanical functions of the robot to improve roving aspects. Integration of methane-detection devices may also be considered.

The effectiveness of laser point-and-shoot devices will be evaluated for their ability to penetrate windows for leak investigation. This will include laboratory testing to explore the impacts of different windows types and coatings.

Researchers will take what was learned in the laboratory testing at a controlled leak-training facility. Testing will include exploring impacts of distance, different windows, and potential leak points on sheds/buildings in the controlled facility.

Laboratory-based and leak-training facility testing will be validated with responder personnel to gain valuable feedback on how technologies may be utilized and integrated into current procedures and what improvements may be necessary.

Extensive data will be collected during the leak-training facility and first-responder training testing. The evaluation will be reviewed and analyzed for recommendations to the use, integrate, and further evaluate these advanced technologies in gas-filled structure leak detection.

Results

In 2021, the project team made key progress, including establishing periodic meetings to discuss the gas-filled structure issue with sponsors and beginning logistics planning for testing. Researchers have also been in communication with robot manufacturers to discuss potential uses/developments for the robots. In addition, the research team is collaborating with some New York-based fire departments to bring their perspectives on training and communication to the project.

Researchers participated in training sessions where handheld laser methane detector vendors trained utility users. The allowed access to information on the limitations of the technologies.

The project team reached out to the Fire and Risk Alliance to obtain information on window coatings.

Researchers participated in a very informative webinar hosted by *Fire Engineering* magazine. The webinar focused on the fire-service side of responding to gas leaks. Fire departments are now relying heavily on laser methane detectors. This highlights a need to facilitate information exchange between gas utilities and local fire departments.

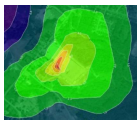
Status

Researchers continue to actively gather information on window coatings in order to perform the most informed and useful testing of the handheld laser methane detectors. Logistics planning for testing at the leak-training facility and participation in emergency-preparedness training are under way.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Advanced Tools for Methane Emission Rate Estimation



The objective of this project is to develop an advanced tool to estimate the emission rate by incorporating spatial methane concentration measurements. If successful, a follow-on project will be proposed to perform field testing and evaluation.

Project Description

Currently, concentration-only measurements are collected in the proximity of gas leaks using handheld devices such as a combustible gas indicators or infrared-based sensors. Leak grading currently relies only on concentrations and locations of the leak, not on the actual emission rates of the leak. This is due to the time-consuming procedures required to enclose and physically measure the leaks.

Researchers note that there is a clear need to advance approaches for determining emission rates of leaks that do not involve physically enclosing the leak.

By leveraging prior research capabilities, this project will develop a robust framework by coupling an air-dispersion physics model and deep-learning algorithms to achieve more accurate methane emission rate estimation.

The objective is to develop an advanced tool to estimate the emission rate by incorporating spatial methane concentration measurements. A comprehensive proof-of-concept study will be conducted to demonstrate the feasibility of this methodology. The emphasis will be on input data format, model development, and deployment platform selection. If successful, a follow-on project will be proposed to perform field testing and evaluation.

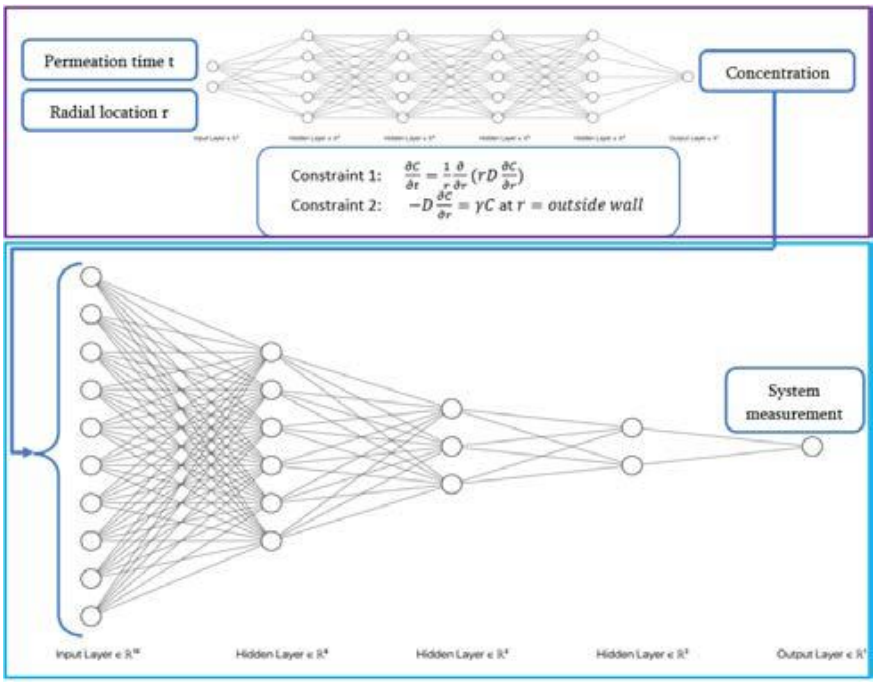
Deliverables

Researchers will provide an advanced analytical tool that can provide more accurate estimation of methane emission rate. A Final Report will be submitted at the end of the project.

Benefits

Developing an advanced tool to interpret field concentration measurement data to produce an estimated leak emission rate has the potential to greatly benefit utilities by increasing the options available to them for quantifying emissions.

For natural gas pipeline or meter set leaks, methane emission rates can be challenging to estimate or quantify due to site accessibly, data limitation, and uncertainties embedded in the measurement process.



Schematics of the explainable neural network

Although not currently widely used by utilities, quantification of emission rates can assist utilities in prioritizing repairs of leaks that are not safety hazards. This prioritization can limit the overall methane emitted to the atmosphere for each leak.

The advanced methodology can be packaged as a software tool and be used in conjunction with concentrations gathered in the field as an additional tool in the leak-repair prioritization tool box.

Technical Concept & Approach

Specific tasks include:

- **Technology and Machine-Learning Algorithm Review**

  In this task, an in-depth literature review will be conducted to gather information on multiple aspects of the methane emission measurement process. Specific focus will be placed on obtaining existing datasets that report in-field concentrations and leak emission rates (something that is not usually readily available). Possible information sources include academic articles, technical reports from industry and research institutions, and specifications of off-the-shelf methane detection tools. The technology review will make sure the developed algorithm is equipped with the capability/interface to incorporate the state-of-the-art measurements. Additionally, the team will review the most recent advancement in machine learning, especially deep-learning methodologies which will serve as the theoretical underpinning of the developed model.

- **Explainable Artificial Intelligence (XAI) Algorithm Development**

  Researchers will design and develop a flexible explainable machine-learning model that incorporates air-dispersion models, field-concentration measurements, and machine-learning algorithms. From both deterministic and probabilistic aspects, it is ideal to utilize a well-defined mechanistic model to predict leak rate at a specific location. However, due to its complex nature, it is challenging to develop a generic mechanistic model to provide accurate emission rate estimation under field conditions. The dramatic advancement of machine learning, especially the emergence of deep learning, provides a powerful tool to approximate the behavior of physics systems as well as correlate system inputs and field measurements.

- **Model Demonstration**

  The project team will demonstrate the process of estimating methane emission rate using the developed tool. Researchers and project sponsors will select a couple of repetitive scenarios to illustrate the model performance. This task will provide the template for integrating the developed tool with a leak survey device for field evaluation in a follow-on project.

Results

The project deliverables were reviewed in depth during the project kickoff call. The following specific deliverables were agreed upon by the OTD sponsors:

- An input data schema and requirements will be developed
- The tool will be tested on synthetic data sets
- The tool will be tested on available data sets to determine how missing or sparse data impacts performance.
- The sensitivity of the model output accuracy to the input data will be reported, and
- Characteristics for a leak-detection device or method will be developed from these activities.

This phase of the project will focus on the tool and its underlying model. The details of sensor systems able to acquire the field data for the model will be pursued in later phases.

Status

The project kickoff call was held in October 2021. The project is in early stages.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Impact of Trace Constituents on Odor Masking

A project team is identifying potential odorant-masking agents that may carry over from incomplete processing at natural gas processing plants. Researchers will determine if the identified compounds will induce a masking effect along with what mitigation procedures might apply.

Project Description

Odor masking is the change in perception of the characteristic gassy/sulfur smell of odorants present in natural gas. This is observed when a chemical analysis of the gas indicates added odorants are present at typical values but are not detectable by a nose because another chemical is present that reduces the odor intensity, changes the characteristic odor, or both.

Efforts are being made in this project to identify potential odorant-masking agents that may carry over from incomplete processing at natural gas processing plants. Researchers will investigate if the identified compounds will induce a masking effect along with determining what mitigation procedures might apply.

In 2021, a utility with an odor-masking issue had gas at a higher than usual amount of heavier hydrocarbons present along with a types of compounds that were unusual, adamantanes. The gas came from a pipeline that passed through a gas-processing facility. The gas prior to processing was reported to contain unprocessed raw products, therefore the identification of adamantane compounds was not unreasonable.

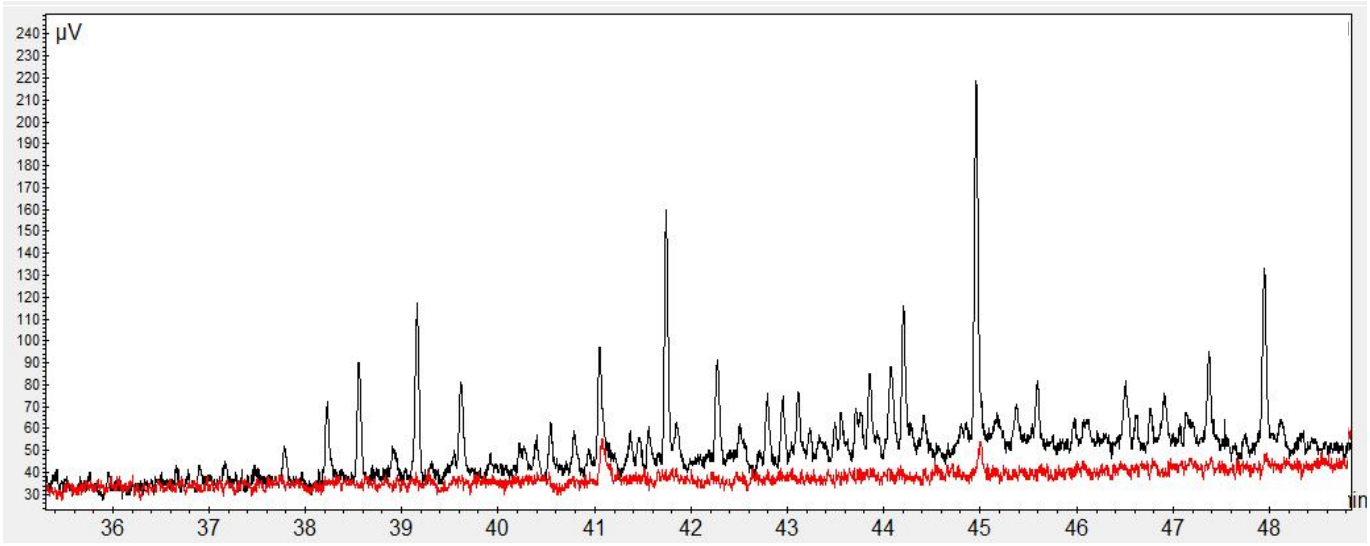
These compounds are known to be present in the unprocessed gas/liquid mixture extracted from the wellhead. Although adamantanes will preferentially partition into the liquid phase, there remains a fraction of these species which can potentially partition into the gas phase. If the gas is not sufficiently processed before pipeline injection, adamantanes could remain in the gas stream. Since adamantane has a strong camphor-like odor, it is possible the adamantane compounds could mask the usual sulfur smell of natural gas from the added odorant.

Adamantanes have not been investigated and there are likely more chemicals capable of odor masking due to incomplete gas processing.

Deliverables

The deliverables for this project include:

- Information on potential chemicals that could induce odor masking and
- Proposed plans for testing actual odor-masking interferences, investigating mitigation procedures, and evaluating potential on-line analyzers to measure specific masking agents.



Gas chromatographic analysis of gases with and without (in red) odor masking.

Benefits

Because methane by itself is odorless, odorants are added to natural gas streams for people to quickly detect a leak if it is present. However, using the sense of smell to detect natural gas can present a problem under certain conditions where the perceived odor has diminished.

The benefits of understanding odorant masking and potential interactions between odorant chemicals and other natural-gas-associated chemicals would allow utilities to be proactive in addressing odor-masking issues by managing suppliers and adjusting odorant-injection when necessary.

Technical Concept & Approach

The project team is performing research into what might be present in unprocessed natural gas that has a potential to mask odor based on the properties of the chemicals.

Specific tasks include a literature survey of the odor-masking phenomenon from the perspective of the natural gas industry and the implications for odorants.

Gas samples with known odor-masking chemicals will undergo a comprehensive analysis focusing on heavy hydrocarbons and other chemicals known to be present in unprocessed natural gas. Discussions with pipeline operators and gas processors will inform the selection of constituents or constituent classes to analyze.

Results

In an April 2021 kick-off call, sponsors were asked for any odor-masking-related gas samples to be sent to the project team. Thirty-six samples were received for analysis, some related to odor masking and some as baseline samples. All samples underwent initial injection and a preliminary inspection of the data was conducted.

The literature search was initiated but has found little information regarding odor masking related to the natural gas industry other than anecdotal reports that it happens. A useful reference describing the relative molecular mass and vapor pressure necessary for having an odor was found and a comparison to common odoriferous compounds tabulated. In general, when two odoriferous compounds that are different in smell are present, a different odor is not usually noted. Instead, there will be suppression of one or the other, or both odors will be detectable.

Publicly available information from a NYSEARCH-funded project was also summarized.

Prior research identified adamantine and related compounds as a potential odor-masking agent. The presence of adamantane compounds also appears to correlate with the presence of heavy hydrocarbons. Both adamantane compounds and the heavier hydrocarbon compounds have a relative molecular mass and approximate vapor pressure that fall within the defined ranges of compounds that can induce odor masking.

Of the 36 new samples, seven did not show the presence of adamantane related compounds. Gas samples with and without known odor masking were analyzed by gas chromatography with mass spectral detection.

Status

Researchers continue to analyze gas samples with known odor-masking agents.

A test plan is being finalized to measure odor masking of selected compounds using sniff jars and human volunteers.

Data interpretation is under way.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Accuracy of Hydrogen Analyzers and Survey Instruments

This project involves a laboratory evaluation on the precision, accuracy, and bias of analytical equipment for natural gas blended with hydrogen at concentrations between 5% and 20%. A variety of current-market leak-detection and leak-survey instruments will evaluated.

Project Description

Before the natural gas industry can consider introducing hydrogen into the grid, an accurate and precise analytical network that can accommodate the gas composition change must first be fully established. Hydrogen concentrations and Btu values will need to be accurately monitored at custody transfer points. Leak-survey equipment must be able to reliably detect leaks and provide accurate and precise readings regardless of the concentration of hydrogen present at the point of analysis.

In 2018, as part of a survey conducted for OTD project 7.17.e *Evaluation of Methane Detection Devices for Utility Operations*, sponsors noted that some of the more common detector technologies are catalytic combustion sensors (CCS), metal-oxide semiconductor sensors (MOS), infrared (IR), and flame ionization detectors (FID). While the CCS and MOS are capable of sensing hydrogen, the IR and FID cannot. As a result, the behavior of survey instruments using these detector technologies will behave differently in natural gas/hydrogen mixtures.

Researchers for this project will conduct a laboratory evaluation on the precision, accuracy, and bias of analytical equipment for natural gas blended with hydrogen at concentrations between 5% and 20%. Various leak-detection and leak-survey instruments will be evaluated.

Deliverable

A Final Report will summarize results of this project. This information will determine a TRL for analytical equipment in regard to natural gas/hydrogen blends. The funders will decide if a public report will be prepared.

Benefits

The concept of blending hydrogen into the natural gas pipeline to reduce carbon emissions has been gaining traction over the last several years. Many online natural gas Btu gas chromatograph (GC) manufacturers

A variety of instruments are being evaluated.

already offer a train or module for their GCs that are capable of hydrogen analysis; however, historically these have not been utilized by the industry at custody transfer sites. As a result, the industry does not have experience with the precision, accuracy, and bias of these hydrogen-analysis systems. Additionally, there is a growing concern related to the impacts of hydrogen on gas leak-detection instrument performance and if the presence of hydrogen will change gas-leak results.

Technical Concept & Approach

A review of instrumentation evaluated and the hydrogen concentration range will be provided. Any additional technologies brought up by sponsors will be considered.

Equipment with hydrogen-analysis capabilities will be obtained for evaluation. A testing protocol will be set up to assess the instrument's accuracy, precision, and bias for determining hydrogen concentration in natural gas at a range of 5%-20%. The design of this protocol will be based on previous testing protocols developed for similar evaluation projects such as 7.16.e *On-Line Biomethane Gas Quality Monitoring* and 7.16.g *On-line Siloxane Detector Testing*).

Based on sponsor response, survey instruments were selected with a focus on representing a mix of sensor technologies. A testing protocol will be developed to evaluate the technical specifications of the selected instruments in the presence of natural gas/hydrogen mixtures.

Results

The project kick-off call to sponsors was held in April 2021. Discussed were the proposed instruments to evaluate for the project.

For the online GC evaluation, equipment was selected based on survey results from a previous sponsored by Gas Technology Institute's Sustaining Membership Program. A question was raised regarding the difference in technologies used in two instruments. Subsequently, a detailed comparison of GC technologies was developed.

The four current-market survey instruments selected for evaluation for this project includes IR, CCS, and MOS technologies.

Sponsors were given an opportunity to provide feedback on the selections and provide alternative equipment options.

Status

Researchers are finalizing the testing protocol.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Developing a Framework for Certifying Responsible Natural Gas

In this project, a research team will create training materials and establish an auditor training program to assess methane emissions for all segments of the gas value chain. The program is based on the protocols developed under Veritas - GTI's Differentiated Gas Initiative.

Project Description

Utilities have the need to integrate methane emissions among gas suppliers, as well as reconcile the various methods to assess emissions among suppliers. Certifying companies are selling responsibly-sourced gas to utilities, but do not integrate emissions of mid-stream suppliers. Utilities are needing a mechanism to integrate the two segments to defend the validity of the gas product to regulators.

Existing methods to report methane emissions are not entirely comparable. For example, one company reports methane-emissions intensity, while another further defines methane-emission intensity as a percentage of gas production. Companies reference some of these initiatives, but also include calculation protocols.

Groundbreaking studies show that bottom-up methodologies miss 60% of methane emissions. The gas industry needs a consistent methodology that is calibrated and verified by measurement and a program to provide consistent training to verify these estimates.

Additionally, many standards do not recommend verification processes necessary for utilities to defend the environmental benefits of natural gas. This includes analytical technologies, frequency of monitoring, and/or state-specific definitions of reduction efforts.

Several companies are about to incorporate or have already incorporated certified gas into their business plans.

In this project, researchers will create training materials and establish an auditor training program to assess methane emissions for all segments of the gas value chain. Materials will be based on the protocols developed under *Veritas – GTI's Differentiated Gas Initiative*. The target audience is auditors of differentiated gas purchased by utilities and utilities themselves for internal auditing.

The project would be commercialized and advertised through Gas Technology Institute's (GTI) training and education services.

Deliverable

The deliverable for this project is the auditor training program, which includes course content and any supportive materials to implement and interpret the procedures produced by the differentiated gas initiative.

Materials would be applicable to third-party auditors of differentiated gas purchased by utilities and utilities themselves for internal auditing.

Organizations standardizing environmental reporting.

Benefits

Organizations currently evaluating differentiated gas are not measurement based. This leaves utilities with numerous products that are not verifiable. The differentiated gas initiative addresses the gap by harmonizing methane-emission protocols and estimation methodologies to include measurement-informed emissions intensities. Creating the auditor training program ensures that the protocols produced by the initiative are operationalized properly.

Third-party auditing is envisioned as an important element of certifying rubrics within different differentiated gas scenarios. When the differentiated gas initiative framework and protocols become available, end users and auditors will need training to ensure adoption of the new measurement-informed methodologies. While utilities may reference the differentiated gas initiative to their stakeholders as the source of defensible, independent methodologies, they may also reference the auditor training program on how to operationalize these methodologies.

Technical Concept & Approach

The project team will organize the curriculum of the auditor training program. This includes soliciting the target audience, defining the objectives of the courses, and planning a timeline to update the program with the latest methane-emission methodologies.

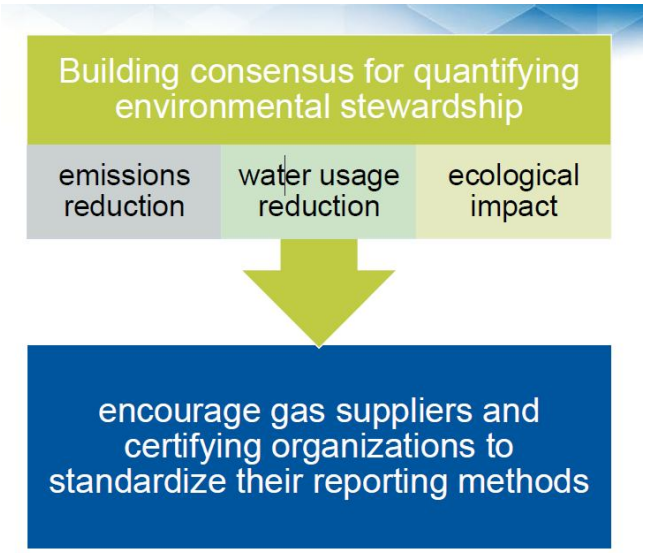
Educational materials will be drafted to audit the harmonized methodologies and procedures produced by the differentiated gas initiative. This task could include creation of additional educational materials, such as rubrics, checklists, and training modules for auditors to better perform the protocols and interpret results. Researchers will also collect feedback from auditors and stakeholders on the defensibility of the auditing approach.

A pilot project is planned for the auditor training program in 2022. Auditor training materials will be edited and finalized following the pilot project.

Results

This project was initiated in February 2021 with a kick-off meeting where stakeholders brainstormed about the recommended framework to certify gas.

With certified gas stakeholders needing measurement protocols for each segment of the gas value chain, GTI created the Differentiated Gas Initiative. Investigators secured partners for the entire supply chain, with plans for the pilot run in 2022.



There are currently no training programs for auditors to understand the methodologies to assess methane emissions or integrate the emission measurements among suppliers. Utilities are at the end of the gas supply chain and most of the emissions are from their suppliers. They depend on third-party auditors to defend the environmental benefits of differentiated gas as part of their climate targets for their jurisdictions.

Current project sponsors will receive project updates on Veritas. GTI created Veritas to write protocols and conduct field trials. The initiative will draft the methodologies for emissions estimation, measurement, and reconciliation for production, gathering/boosting, liquefied natural gas, transmission/storage, and distribution.

Status

The project team and sponsors are making efforts to determine how auditor training will fit into existing regulatory and voluntary audits of methane emissions of gas.

The auditing and assurance protocols are being written by Veritas.

The format of the curriculum (e.g., e-learning series, in-person workshops, webinars, etc.) will be determined as the target audiences provide comment on the envisioned training program.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Advancement and Testing of a New Handheld Laser Methane Dector

Research is being conducted to advance and evaluate a novel remote methane gas leak detector to improve gas leak survey operations. The project's ultimate goal is to demonstrate that this technology is convenient to use when deployed in real-world operations, meets stated performance specifications, and complies with regulations.

Project Description

Measuring natural gas leak rate improves safety by assessing the severity of the leaks, allows prioritization of repairs based on highest leak rates found, and reduces greenhouse gas emission concerns.

In this project, researchers are specifically investigating a remote methane leak detector (RMLD). This laser-based tool has been used in leak surveys since its release in 2005. A laser scanner was integrated into the RMLD package to provide sensitive quantitative imaging of small leak plumes and calculation of their emission rates. The information acquired by scanning the RMLD laser beam across or around a leak source is processed to create a plume image and deduce emission rate independent of ambient conditions.

In industry-sponsored projects, a prototype was deployed from a minivan to capture the first-ever video images of small fugitive leaks from municipal distribution pipelines and quantify the leak rates. The system was subsequently repackaged to be a portable, handheld unit.

As part of this new project, operating techniques and algorithms for deducing methane flux and emission sources will be advanced and optimized. Minor modifications to hardware will be made to improve portability.

The overall miniaturization to a handheld unit is being performed in a parallel program effort. The Quantitative Gas Imager (QGI) provides the user images of the background scene overlaid with two-dimensional spatio-temporal maps of path-integrated methane concentration versus position. It is capable of gathering these images from distances (50-100 feet) safely away from the source of the plume. Knowing the local air speed and direction, the tool estimates methane emission rates and path-integrated concentrations.

For compliance with natural gas leak detection regulations, this platform is expected to be equivalent or superior to the industry-accepted OGI tools at significantly lower cost.

The project's ultimate goal is to complete rigorous validation tests demonstrating that this technology is: 1) Convenient to use when deployed in real-world operations 2) Meets stated performance specifications, and 3) Complies with regulations requiring novel leak-detection solutions to reduce methane emissions.

Current sensors cannot reliably deduce methane flux of small plumes observed against certain background scenes (e.g., dark surfaces) – a technology gap this project addresses.

Deliverables

Deliverables include a test plan and test results with analysis summarizing performance. A Final Report will be produced and a final conference/webinar to review the results of the program and detail the envisioned next phase for real-world field evaluation and validation.

Benefits

Most of the ~250 billion cubic feet of annual natural gas leakage volume originates at relatively few large leak sites. Identifying and repairing those leaks is expected to mitigate approximately 90% of the loss, worth about $2 billion. Thus, the principal purpose of developing rapid and remote leak-rate measurement techniques is to rank leaks based not only on the current practice of measuring local concentration (which can be very high for a small leak in a no-wind condition), but also on measuring leak rate. QGI provides emission rates at each inspection site, enabling the prioritization of repairs. This allows the operating companies to focus their repairs on major leaks, improving the safety of the system and maximizing savings in recovered loss gas.

Technical Concept & Approach

Specific tasks include:

- **Operational Firmware Development**

  In this task, operational firmware will be written and installed onto a central computing device. Specifically, the ability to operate the QGI in multiple scanning modes will be enabled. This will be a critical feature for enabling the dual-mode operation – a Survey Mode and an Imaging and Quantification Mode.

- **Controlled Laboratory Testing**

  The project team will conduct controlled laboratory testing to acquire baseline performance data of the updated QGI system and to perform an assessment of the usability of the system. Based on initial testing, the QGI prototype will be revised and updated for higher-performance quality and better usability, as needed.

- **Algorithm Development**

  The leak-rate estimation algorithm will be refined using previously collected data and new data collected with the mobilized RMLD QGI. Based on lessons-learned from previous testing campaigns, two algorithm development initiatives will be explored to address two scenarios – a leak that can be fully encompassed in a single scanner frame (i.e., a pinhole meter-set leak) and a widespread leak that requires multiple frame locations to encompass the leak (i.e., underground leaks). Based on evaluations of the updated algorithms, alternative scanning routines may be investigated to further improve the algorithms.

- **Controlled Field Tests**

  Researchers will conduct controlled leak tests intended to validate instrument performance. Prior to executing the tests, the team will develop a comprehensive test plan. The controlled leak scenarios will provide experience in operating the instruments in realistic operating conditions, establish baseline performance metrics to compare with previous laboratory and ad-hoc data, and provide data for improving leak-rate estimation algorithms. Example test variables include background surface type and distance from leak. Researchers will review the test results and provide a summary detailing performance statistics such as time to find leaks, leak size classification (small, medium, large), and leak-rate estimations accuracy. The tests will also provide the opportunity to modify system operations to achieve an intuitive, easy-to-use sensor system, and to further refine and calibrate the leak-rate estimation algorithm.

  With successful validation at the laboratory, a follow-on phase is anticipated to conduct real-world field validation tests in collaboration with potential industry users.

Results

In 2020, controlled testing of the latest version of the QGI was conducted. During this test campaign, the QGI evaluated 26 controlled meter-set leaks ranging from 0.1 to 5.0 standard cubic feet per hour (SCFH), four controlled underground leaks ranging from 1 to 30 SCFH.

In 2021, the project team worked on evaluating integrated scanner modes and algorithm development. For algorithm development, the application of the baseline algorithm was initiated to new scanner modes. Efforts were also made toward the selection of alternative/ optimized algorithms developed under similar quantification initiatives.

The project team fully implemented the QGI platform into the RMLD form. PC software was updated to process the new scanner modes and data streams. General operations of the handheld device were tested.

Status

Researchers are evaluating concentration mapping on an integrated handheld display. Mapping firmware is being developed.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

INTELLIGENT UTILITIES

Developments in this area include the use of advanced data-collection, management, and information technologies to improve the safety, reliability, and efficiency of natural gas operations.

Efforts are being made to develop, commercialize, and implement technologies to automate data collection, reduce manual data entry, enhance data quantity, and reduce data-entry backlogs.

The program is aimed at delivering software, hardware, standards, and procedures to improve the accuracy, consistency, completeness, and relevancy of information and ensure regulatory compliance.

Current efforts include the development of a process visualization and reporting capability, smart phone tools, 3D visualization software, and the development of industry-supported standards for transmission tracking and traceability.

.

Tracking and Traceability Marking Standard for Natural Gas Transmission Components

The goal of this project is to enable the capture of key information required for physically documenting and geospatially modeling new or repaired gas transmission systems to meet the regulatory requirements.

Project Description

This project focuses on the development of a new marking standard for natural gas transmission components. By designing the marking standard specific to the various components encountered in a natural gas transmission system, and taking advantage of newer barcoding technologies, it is believed that the standard will provide value not only in the gas industry, but potentially to other utilities as well. The development of a new standard provides a comprehensive path to accommodate the wide variety of components found in a natural gas transmission system.

The specific goal for this project is to enable the capture of key information required for physically documenting and geospatially modeling new or repaired gas transmission systems to meet the latest regulatory requirements.

Three major developments are being pursued:

1. Development of a machine-readable marking standard for all steel natural gas transmission system components

2. Construction of automated field-data-collection processes linking the required manufacturers' inspection and test documentation and supporting the automated definition of each field-installed component, and

3. Acquiring industry acceptance for publication of the standard under one or more standards organizations.

This project used existing technology developed in Phases 1 and 2 and added additional key capabilities in two additional pilots to demonstrate a complete technology solution for marking natural gas transmission components. The solution associates product information using a Global Data Synchronization Network (GDSN) and a document store for delivering inspection and test data for utilities for products purchased for capital or maintenance projects.

The system takes advantage of GS1 standards to mark components and subassembly parts. The standards automatically enable indexing and storage of documentation for each component during intermediate manufacturing steps, at multiple material handling steps and at the end-user's site to fully document all components installed for service.

Deliverables

Deliverables include:

- A working protoype system capable of being transported to industry conferences to demonstrate the new standard's use in manufacturing, shipping, warehousing, and construction
- A Final Report in the form of a purchasing document for invoking the use of the new marking standard, and
- An implementation roadmap and recommendations for the new transmission marking standard.

Benefits

The experiences of using intelligently marked plastic distribution components has shown to significantly reduce the time to document a new or repaired natural

Piping with GS1 barcodes developed with industry marking standards.

gas distribution system. With the establishment of the marking standard for natural gas transmission lines, utilities should be better equipped to construct their transmission facilities and implement controls over establishing the required documentation.

Technical Concept & Approach

In addition to marking standards development, efforts are being made to:

- Establish new application identifiers for fields (Utility Component Type and Heat Number) required to support the new transmission marking standard developed in Phase 1.
- Establish a voting membership at GS1
- Continue the demonstration mobile software technology to use in pilot systems for collecting key information from marks on transmission components
- Conduct pilot programs to demonstrate the new standard's ability to provide accurate track and traceability for components used in the construction of natural gas pipelines, and
- Develop processes, procedures, and protocols to stage and manage inspection and test documentation for components.

Results

Initially, the project team reviewed manufacturing standards and marking requirements for the many different transmission components and found that the marking standards primarily focused on identification of the product, almost exclusively, in a human-readable form. After reading a number of the manufacturing standards, researchers identified GS1 standards, the original marking standard developed and put into use in 1974 for marking products in retail operations. The GS1 standard's architecture has been used by many key industries to achieve a high degree of tracking and traceability. GS1 standards are made available in the public domain and are not propriety to any specific industry.

In 2018, researchers defined the individual properties that are to be included in the new mark for the transmission components. The marking standard is being organized by component class with specific rules developed for each class of components. The architecture sets three levels of information to be included in a utility mark, covering product definition, quality and security, and graphic/geospatial modeling properties. Researchers are developing a structured specification for each of the properties to be included in the marks for each class of component.

In 2019, research continued on the final set of marking standards for the project. The standards are intelligent GS1-based functions contained in a 2D barcode and a standard set of attributes for each component class, pipe, valves, assemblies, fittings, and general utility components. The project team completed the scope for the development of the first phase of software to run on iPhone and iPad for scanning direct part marks on transmission components that comply with the standards from this project.

In 2020, the project team continued software development and initiated attribute-data development for two pilot programs. The marking guidelines were updated to permit multiple keys that point to inspection and test documentation concerning a specific instance of a component. Additional references are also now supported as are product properties such as specifications, drawings, photographs, reports, and other multimedia information.

Sixteen barcodes were readied to test. Additional information must be added to these barcodes to register the coating system documentation once completed.

Researchers also developed preliminary models for tracking documentation associated with assembled fitting constructed from multiple subcomponents.

In 2021, the research team defined attributes forming the data model for pipe fittings and loaded three transmission components into GDSN. This step provides a path forward for a much more realistic pilot program.

The project team continued building synchronization processes to run on its server systems, automatically adding data from a component manufacturer into its pilot systems from GDSN.

Additional attribute data for components in the form of multi-page user manuals, specification sheets, and digital images of products with dimensioning were incorporated into the GDSN data model.

Status

Researchers continue development of the two applications – building documentation assemblies for fabricated components and a mapping-as-built construction application.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

GNSS Smart Applications for Field Data Collection

Efforts are under way to increase the quality and consistency of location data collected by the natural gas industry through the use of Global Navigation Satellite System (GNSS) receivers. The approach is to automate certain steps of the data-collection process and reduce the burden on field-data-collection personnel.

Project Description

For several years, OTD has supported research into the evolving nature of Global Navigation Satellite System (GNSS) technologies for the natural gas industry via the GNSS Consortium project. Through the consortium, various GNSS receivers were investigated under real-world testing scenarios mimicking typical gas-industry workflows.

In Phase 1 of this project, a research team created a prototype hardware add-on which helps the field-data-collection personnel apply the correct operating procedures while handling the GNSS receiver. The system also increases safety by allowing data-collection steps to be broken down into two phases so that the user is only required to handle one device at a time. Ten prototypes were assembled, provisional patents were filed, and commercialization planning initiated.

Phase 2 included hardening the physical form-factor to better support durability in the field. Researchers will also offer to support field pilots of the second-generation prototype to allow customers to learn more about the product and to provide comments on its real-world application. Phase 3 involves modifications.

The goal is to develop sufficient documentation so any vendor could assemble the hardware and configure the software in an on-demand fashion for any customer.

Deliverables

This goal for this project is to produce a software and hardware technology that operates between the user's existing GNSS receiver and existing field-data-collection smart devices.

Benefits

Data quality is an important issue for any organization operating in today's information technology environment. High-quality data allows for detailed and reliable analysis that can support optimizations to business efficiency and improve input to risk assessments and management.

This technology will help ensure consistency and verify that quality thresholds are satisfied through automated data collection. Additionally, the technology will reorganize the collection process so that the field-data collector is required to operate and handle fewer components during any given step.

Increasingly, it is necessary to pair field-collected data with high-quality geographic locations suitable for mapmaking and other geographic information system analysis functions. Research into GNSS devices shows that the best predictors of quality are first the capabilities of the hardware device itself and, a close second, the techniques and practices used by the field-data collector. Standardizing the collection process through smart automations can increase the accuracy of the GNSS position.

The hardware device being pursued in this project will provide access to accuracy-helping functions at a financially feasible price point.

Assembled units.

Technical Concept & Approach

Test-case documentation is being created based on the requirements and design documentation. The test cases exercise each function, service, and design element. Researchers will execute each test case multiple times and record the actual results of the test. In cases where the actual results do not satisfy the expected results, the project team will re-work the prototype until the system passes all tests.

A set of second-generation prototype units were built. The hardware subsystems and customer software modules are being updated to support Bluetooth connections to various mobile devices. Researchers will construct up to 20 duplicates of each prototype for each company who is interested in on-site field demonstrations, training, or pilot-project implementations.

Results

In Phase 1, a total of 10 prototype units were assembled and field tested.

Employing a model-driven approach, researchers identified a set of hardware and software components that could be used as a platform. A Single Board Computer (SBC) running an embedded Linux Operating System was selected, specifically the Raspberry Pi 3 (RPI3), as the primary computer environment. The RPI3 fell under the weight and size requirements, is available as a low-cost consumer product, and is supported by many open-source organizations. Another key reason for choosing the RPI3 is the availability of an all-in-one sensor system and LED display called the Sense HAT. The Sense HAT is designed for the RPI3 and contains the nine degrees of freedom sensors required to detect a perpendicular orientation.

A set of custom software scripts were written to encapsulate the required algorithms for automating the collection of high-quality point estimates from the GNSS device.

In 2019, for Phase 2 researchers completed development of new software components and the creation of a 3D-printed case. The project team prepared two Phase 2 beta prototypes for systems testing. A three-phase approach was chosen for unit testing, integration testing, and systems testing.

In 2020, a demonstration was conducted and software modifications were made in support of anticipated hardware changes. The current Phase 3 further improves the system's existing features and provides additional features. Integrating the chip with the unit will eliminate the need for a separate GNSS device.

In 2021, hardware was the primary focus of activity. The design of the system's main printed circuit board (PCB) progressed very near to completion. A vendor that can produce the circuit board has been engaged. Preliminary research on the enclosure has commenced, facilitated by the purchase of a small 3D printer for rapid prototyping.

"Capturing high-quality geospatial coordinates of our assets is a vital component of producing traceable, verifiable, and complete as-built records. The GNSS Smart Automation box will automate a major step in the data-collection process instead of relying on the field user to optimize the quality of the GNSS at the time it is recorded."

- Stephen Jeong
Senior Gas Engineer
Gas Operations R&D and Innovation
Pacific Gas & Electric Company

A substitute for the inertial measurement unit chip used in the development phase of the project had to be found because additional units of the original chip are not available for building the final prototypes. This substitute was identified and tested for suitability. A similar situation exists for the Bluetooth chip. Rather than finding a substitute chip, the plan is to remove the current chips from their development boards to use them on the main PCB in the final Phase 3 prototype.

Currently there are two complete, functioning units. Some minor hardware assembly, printing of cases, and software installation are expected to yield two more units.

The design allowed for hosting all of the electronics and mounting the on a survey pole. A built-in mounting bracket was designed to attach the system at any height on the pole, preferably on the user's eye level, to see and access the device easily.

The software was tested and refined based on test results.

Status

Software testing and refinement is being completed.

The project team will provide demonstrations to sponsors. Virtual demonstrations can also be arranged for other participating companies.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Low-Cost RTK Base Station

The objective for this project is to promote the wide adoption of high-accuracy Global Navigation Satellite System (GNSS) technology by removing barriers to the implementation of real-time kinematic (RTK) technology. Research is focused on increasing access to data and creating an inventory of publicly available base stations.

Project Description

The natural gas industry is motivated to place high-quality Global Navigation Satellite Systems (GNSS) technology in the hands of an increasing number of personnel. Consequently, gas utilities hold a special interest in lowering the per-user cost of systems so that achieving high-quality data is economically feasible.

As part of the GNSS Consortium, OTD supported a formalized receiver testing program conducted that indicated that real-time kinetic (RTK) GNSS systems are the most reliable and efficient methods for achieving high-accuracy position estimates. RTK receivers not only produce points that are both accurate and precise to a few centimeters, they also do a better job coping with the various problems associated with difficult real-world data-collection environments.

Low-cost RTK system training in Decatur, IL.

In recent years, researchers have been collaborating with several gas utilities in efforts to remove barriers to implementing these systems across individual utilities. In 2016, research was completed on a project sponsored by Gas Technology Institute's Sustaining Membership Program (SMP) to investigate the possibility of creating low-cost RTK base stations as an alternative to fixed-base stations. The SMP project developed two versions of proof-of-concept portable base stations. The project proved that temporary portable base stations, which run on batteries and register their own location at boot up, are feasible.

This project builds on the SMP project and focuses on increasing access to base-station data by creating an inventory of publicly available base stations, testing a publicly available base station at a long distance, and continuing the development of low-cost, portable, base-station technology.

In Phase 1, researchers tested the performance of low-cost RTK base stations in conjunction with low-cost RTK rover receivers. Phase 2 involved pilot projects to further evaluate the technology. The current Phase 3 explores the capabilities of a device to be used with software and the RTK network infrastructure.

Deliverables

Project deliverables include:

- A catalog of publicly available base stations
- A base station comparison report
- Prototype hardware
- Prototype software source and deployment
- Requirements analysis documentation
- Design documentation, and
- Test cases and test-case results.

Follow-on steps include discussions with potential vendors, enhancements of the technology as needed, operator field tests, and pilot programs.

Benefits

Gas utilities share a common strategic goal to be safe, reliable, and compliant suppliers of natural gas. More and more, the business activities and processes necessary to achieve safety, reliability, and compliancy goals either produce and/or rely on high-quality data. Achieving these goals at a lower cost would contribute to the efficiency of the organization.

Technical Concept & Approach

- **Cataloging and Testing Publicly Available RTK Base Stations**

  The project team researched and documented a full list of free base stations operating in the United States. One drawback to public base station data is that the effectiveness of the correction data degrades the further away the receiver unit is from the base. Researchers conducted a comparison test between the accuracy of a traditional, private, fixed-location base station and a public base station a distance away.

- **Portable Base Station Design and Development**

  Researchers detailed the requirements and design for a portable base station. All documentation will contain sufficient detail so that a third-party commercial vendor could reproduce the unit upon request.

- **Prototype Testing and Re-Work**

  This task included creating test-case documentation based on the requirements and design documentation. The test cases exercise each function and design element.

- **Pilot Projects**

  The system was evaluated in pilot projects with program sponsors.

Results

The results of testing were somewhat unexpected. The original hypothesis was that if a high-cost system may reliably produce one to two centimeters in accuracy and precision, a lower-cost alternative RTK system could be found which would produce about 30 centimeters. However, testing revealed that the lower-cost units produced similar accuracies and precision value to higher-cost systems when the unit was able to achieve an RTK fix solution; but the lower-cost units took longer to acquire an RTK fix, lost RTK fix status more frequently, and in some cases could not acquire an RTK fix solution. In other words, the tradeoff for low-cost systems was shown to be in reliability and performance rather than in precision and accuracy.

In 2019, Phase 2 pilot projects were designed. A newer system was released that on average produced horizontal locations when achieving an RTK fix that was 1.7 centimeters from the actually known point with a precision of 2.5 centimeters under real-world conditions. Additionally, the system produced vertical measurements averaging 0.7 centimeters below the know elevation with a 1.8 centimeters standard error. The second-generation model has significant improvements, most notably the ability to receive satellite message broadcasts on multiple radio bands.

In 2020, the project team delivered a demonstration for two sponsors.

In 2021, researchers initiated a process to set up a subcontract with a vendor. Testing equipment was procured, and some initial testing performed.

An investigation and testing were performed to check the compatibility of new system. Testing the device's compatibility to act as a base station within the vendor's RTK network infrastructure was successful. It was determined that integration requires further development and cannot be satisfied within the current scope and budget of the project.

Status

Researchers believe that the integrations required to deploy a low-cost system as a mobile, permanent, or semi-permanent base station are possible. However, additional development is required.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Technology for 24/7 Leak Detection

The objective for this project is to integrate a suite of existing technologies into a prototype 24/7 leak-monitoring system. Researchers investigated state-of-the-art methane sensing, wireless connectivity, and web-hosting technologies.

Project Description

The increasing necessity to detect, monitor, and mitigate methane emissions drives the need to automate some tasks in this area. Routine activities such as patrolling construction sites or high-consequence areas now require visits by personnel. There are also facilities, such as gates or large regulator stations, that need periodic attention. Automated monitoring of these areas would allow personnel to be dispatched where most needed.

OTD has sponsored several efforts that involve measuring leak concentration or flow and delivering the data wirelessly. These projects produced prototype tools that address specific use cases, such as:

- Investigative tools for first responders
- Leak classification by flow rate, and
- Unattended monitoring of known leaks.

The use cases that these past/ongoing efforts addressed have all been reactive: a leak call was made and mitigation is in progress. They are monitors rather than detectors. A suite of base technologies was developed in these projects that can be redeployed or extended. The objective for this project is to integrate a suite of existing technologies into a prototype 24/7 leak-monitoring system. The system will use state-of-the-art methane sensing, wireless connectivity, and web-hosting technology.

Deliverables

The following deliverables are expected to result from this project:

- A use-case specification for an automated leak-detection system for temporary deployment
- Description of the data that the sponsors require from a leak-detection system

- A reference design for the component modules required to construct prototypes of the leak-detection systems
- Construction and testing of prototypes, and
- Deployment of the prototypes at utility test sites.

Benefits

The deployment of an automated system for continual leak monitoring would provide benefit in terms of resource allocation and scheduling. Personnel could be freed from some routine leak-patrol activities. Information provided by the monitor can be used to target personnel activities where they are most required.

Technical Concept & Approach

Specific activities include:

- **Project Scoping**

  The project team defined the requirements for a 24/7 detection system. There is a need to differentiate temporary and permanent use cases as these will have different requirements. The sensor types, ranges, and sensitivity and ranges were also determined.

- **Preparation of a Reference Design**

  The design will be as modular as possible to support the re-use of hardware between temporary and permanent installations. A modular power supply that can be battery- or mains-powered will be developed.

- **Construction and Testing of Prototypes**

  In addition to electronics and power modules, the project team will fabricate housings specific to permanent and temporary detector nodes.

- **Deployment of Prototypes**

  Test sites for the leak detector nodes will be solicited from the sponsors. The project team will provide training with the detector prototypes and assist in deployment.

- **Data Analysis and reporting**

  Investigators will capture test deployment data traffic that will be maintained specifically for this project's data. The research team will use the data to analyze the detector system performance. The data and findings will be provided to the sponsors on a regular basis.

Results

The path being followed is to develop common processor and sensor modules, but several versions of the power supply and communication modules. This will allow the maximum amount of re-use but still allow some customization for different missions.

Sensors are being investigated that provide sensitivity to methane down to 0.1% gas by volume, low-power operation, and quick (30-45 seconds) warm-up time. Additional environmental sensors that provide temperature, humidity, barometric pressure, and the presence of volatile organic compounds were also investigated. These sensors would complement the primary goal of gathering methane data.

In addition, the sensors have: long-term stability, built-in serial interface that simplifies support hardware, real-time auto-gas calibration and built-in environmental compensation, and no catalyst (therefore poison-resistant and intrinsically safe).

In 2020, researchers identified and investigated a software package used to evaluate the positioning of multiple sensors for optimum coverage. The project team found that there are multiple technologies in hand that can accomplish 24/7 monitoring. All approaches have the same basic modules that must be tailored to the specific use case. Versions of these basic modules were developed that can be combined to fit a given use case.

A use case of interest was identified is one that includes the possibility of detecting multiple species of gas being present. One of the previously identified sensors can differentiate gas by molecular weight. The sensor does not provide detailed constituents but can differentiate between hydrogen, methane, and heavier hydrocarbons.

Status

The Final Report is currently being prepared.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Incorporating Pipeline Safety Management Concepts into Existing Programs

Researchers are using business-analysis processes to develop methods to improve overall organizational safety by broadly implementing pipeline safety management concepts across existing programs and technology platforms. The objective is to develop a set of tools that assist gas utility organizations in creating new or updating and validating existing business processes.

Project Description

Gas industry regulations, specifications, standards, and best practices change or update frequently. Additionally, new equipment, changing personnel, and an increasing amount of documentation to collect make some of these processes complicated, leading to difficulty in achieving and maintaining the highest-quality safety practices.

New business-analysis tools and techniques can help to manage organizational transformations required to keep pace with these mandated changes. Using a standardized approach, utilities can learn from each other to find process-improvement opportunities that can be implemented in an efficient manner. The analysis known as Business Process Modeling and Notation (BPMN) allows for even complex processes to be better understood and executed by leveraging a process that identifies gaps, clarifies needs, and provides the necessary link between process design and actual implementation. These process models also allow for companies to more clearly understand how change will affect their organization.

For this project, the research team will facilitate the knowledge transfer of existing best practices while also evaluate how to update current business processes to adopt those best practices. The objective is to improve overall organizational safety by broadly implementing pipeline safety management concepts across existing programs and technology platforms used to support the activities of those programs.

During the Phase 1 effort, the project team was able to successfully reduce standard API RP 1173 to each of its unique requirements and recompose them in a more consumable process-based organization using BPMN tools. Doing so laid out a framework to execute pilot programs identifying an individual organization's unique business processes.

Phase 2 involves the development of a set of tools that assist gas utility organizations in creating new or updating and validating existing business processes that implement the required characteristics documented in API Recommended Practice (RP) 1173.

Deliverables

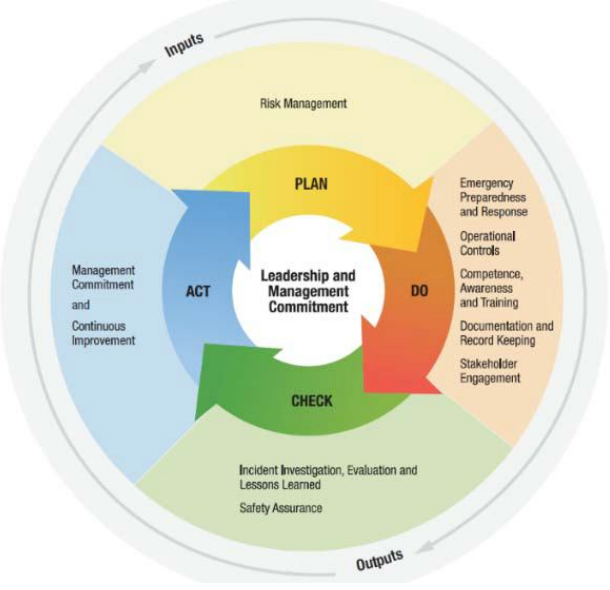
The project deliverables include:

- All BPMN documentation
- Recommendations
- Implementation at one utility
- A Final Report, and
- A webinar presenting project results.

This initial project phase addressed the safety aspects common to most utilities. Future phases could include pilot-project implementations of transformed processes on an on-demand basis.

Benefits

- Increased safety via broader application of pipeline safety management concepts into more programs and
- Reduced costs associated with risks and unintended consequences related to business changes.



Original diagram from API RP 1173.

"Southern Company Gas is proud to continue our partnership with OTD to further understand the role of process mapping to support implementation of a Pipeline Safety Management System framework. Advancing pipeline safety is critical to ensuring access to clean, safe, reliable, and affordable energy for our customers and communities."

- Zachary Lowe
Director of Pipeline Safety Management
Southern Company Gas

Technical Concept & Approach

The scope of this project includes applying business-analysis techniques and tools to gather requirements, record existing processes, identify gaps, and provide implementation recommendations including best practices. The project team will research and identify the techniques that are best suited for managing business changes that incorporate pipeline safety management practices into existing programs.

Researchers will elicit requirements from stakeholders using standardized best practices. This will be comprised of any or all of the following: interviewing system users, brainstorming, documenting observations, gathering survey information, and/or reviewing existing regulations and standards from regulating authorities.

Based on the requirements collected, the project team will provide analysis documentation. Researchers will leverage methodologies from past projects to document business processes, requirements, data models, and other specifications based on information collected.

The project team will provide a recommended approach for implementing the best practices and transferring the knowledge compiled in previous tasks. Plans are to involve one utility in the implementation of these best practices.

Results

In this project, researchers evaluated developing simplified ways for utility organizations to implement best practices. The project team initially researched standard API RP 1173 into its core requirements and identified each business process that supports those requirements to expose gaps, coordinate communication, and introduce enterprise-level management of pipeline safety management systems (PSMS).

With major gas utilities, researchers tested the methodology and identified areas for improvement. From there, the project team focused on two of the 10 essential elements, finding that even in areas where processes are firmly established, there are still areas for refinement and gaps identified. As a result, the research team found that this approach is well-suited to support PSMS processes and enable enterprise systems to assist in better decision-making capabilities.

The project team documented associated reference materials using business analysis techniques. Researchers also interviewed subject-matter experts that have previously gone through various forms of gap analysis related to programs to better understand how the business analysis approach can help supplement these programs. Additionally, a survey was issued to discern the status of industry adoption of PSMS.

In 2021, researchers met with sponsors to discuss successes and challenges in implementing pipeline safety management programs. Areas of concern were incident investigation, evaluation, and lessons learned.

One item that has been consistent throughout is the lack of software or technology to help track and report on progress.

During the second quarter of 2021, the project team added a PSMS consultant to the project. Working directly for utilities, this consultant has experience creating culture shifts that remove roadblocks and move organizations toward more mature pipeline safety management programs.

The team also created training videos to explain the concept of BPMN, the notation, and steps you through some examples.

Important to note, decisions points of project sponsors are further supported through insights published from the Bureau of Labor Statistics, the U.S. Energy Information Administration, and various other resources.

Status

Researchers are preparing to unveil an Educate & Enable PSMS market strategy with stakeholders to solicit feedback, garner support, and increase clarity.

This project is one of several efforts being performed across the industry related to PSMS. To maintain alignment and maximize value intended from this project, project leadership will be engaging with the American Petroleum Institute's PSMS leadership. This effort enhances this project's likelihood in reducing duplicative efforts all the while adding high value to macro-PSMS needs across the gas value chain.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Augmented Reality (AR) Technology for Performing O&M Tasks

AR technology can help bridge knowledge gaps and can be used by field personnel within the natural gas industry to assist with performing O&M tasks. The goal of this project was to demonstrate the value of this technology and identify intuitive software applications and hardware equipment preferred by the natural gas industry.

Project Description

The objective of this project was to identify and evaluate AR software applications and hardware equipment (i.e., wearables and handheld) that can be used by field personnel within the natural gas industry to assist with performing operations and maintenance (O&M) tasks.

The goal was to demonstrate the value of this technology and identify software applications and hardware equipment preferred by the natural gas industry.

Deliverables

The deliverables for this project include a Final Report detailing the AR software applications and hardware equipment best suited for the natural gas industry. This report also highlights findings from a project sponsor pilot study.

Benefits

AR technology can help bridge this knowledge gap and also aid employees that do not perform the same type of work on a regular basis.

AR technology has proven to improve the following:

- Accuracy of work performed
- Employee productivity
- Safety of employees
- Compliance documentation
- Collaboration and communications, and
- Customer service.

AR technology allows field personnel to access O&M procedures, checklists, troubleshooting tips, previous maintenance records, and training aids, and communicate with subject-matter experts in remote locations to assist and provide guidance on their activities, all hands-free. This technology also allows for video recording and photos of the work being performed or completed, leading to better documentation.

Technical Concept & Approach

Specific tasks include:

- **Identification and Evaluation of AR Software Applications**

  The project team identified and evaluated potential software applications that may work well within the natural gas industry. Project sponsors selected the type of work activityto use as part of the evaluation process.

- **Identification and Evaluation of AR Hardware Equipment**

  Researchers identified and evaluated potential AR hardware equipment that may work well within the natural gas industry. Sponsors were given the opportunity to select which equipment to test.

- **Develop and Program Procedure Content into AR Application**

  This task included the project team members working directly with the AR software service providers to develop and add the O&M procedures selected by the project sponsors to enter into the AR application. Types of documentation include work procedures, checklists, manufacturers installation guides, training guides and videos, etc. Additional performance enhancements were made.

- **Pilot Study**

  A pilot study with project sponsors using the AR software application and hardware equipment was conducted.

Results

During this project, software and hardware AR technologies that can be readily deployed were evaluated based off feedback from volunteer pilot project participants. A survey was prepared to provide a better understanding of how sponsors would like to use the AR technology and identify which types of procedures they would like to see as part of the pilot project for evaluating the technology.

A pilot-project test plan was developed and discussed with pilot volunteers. This plan allowed the sponsors to assess each step-by-step procedure/remote mentor software application and provide feedback to the project team about their needs, concerns, and observations.

Pilot participant feedback was collected on six software applications and five wearable hardware devices. At the conclusion of this technology evaluation effort, two intuitive software applications and one wearable device preferred by the natural gas industry were identified as top-performing candidates for further assessment of AR technology.

To complete the Phase 1 evaluation, a 16-week pilot project was performed with volunteers from four sponsoring companies. During this pilot, training sessions with the research team and the technology providers were performed. During these sessions, the pilot volunteers were able to observe and experiment with the various features. After these sessions, feedback was collected and delivered through qualitative question/answer sessions and through online quantitative surveys completed at the end of the pilot.

The Final Report details the technologies evaluated, scoring criteria, and overall results produced from pilot volunteer feedback.

Feedback was provided on:

- The functionality of readily deployable AR devices
- A comparison of these options with competitive AR devices
- The field operator, subject-matter expert, and administrative user experiences of using step-by-step guided procedures and remote mentor; and
- A comparison of industry leading AR-enabled software tools that provide step-by-step procedures and remote mentoring.

To conduct the software evaluation during this pilot, researchers pre-generated several industry-specific procedures, such as performing a butt/electric fusion or installing a mechanical coupling.

Status

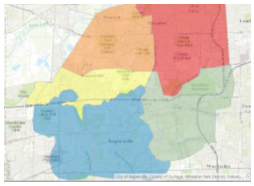
This project is complete. A Final Report was issued in March 2021. A Phase 2 effort is being proposed to provide interested pilot volunteers with AR software licenses and hardware devices. During the pilot, a project team will develop a list of high-priority procedures for pilot volunteers to deploy using AR technology.

The project team also recommends that future research continues to identify, evaluate, and test intrinsically safe devices used to access the top-rated AR platforms, specifically, tablets and smart phones in a Phase 2 follow-on project. Researchers also recommend that a library of gas distribution content (e.g., procedures, checklists, training, etc.) on each of the top-rated AR platforms be developed for stakeholders to access.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

High-Accuracy Mapping of Leak Surveys



In this project, researchers developed a framework to couple high-sensitivity methane/ethane sensors with high-accuracy Global Navigation Satellite Systems (GNSS) for on-foot gas leak investigations and walking surveys. This has the potential to reduce the amount of time that technicians need to spend investigating, documenting, and tracking a leak.

Project Description

With current analyzers used for high-accuracy mapping of walking leak surveys, the resolution is not capable of the granularity of measurements needed. In addition, the analyzers were created for specific applications and do not typically have a readily available way to integrate data into an automated system. There is also a lack of capability to determine ethane concentrations in near real time to allow the operator to distinguish between natural gas and other sources of methane, such as sewer gas.

Pairing the product with one of the newly developed high-accuracy methane sensors would alleviate these issues.

The concept for this project originated while performing field testing on OTD project (7.17.e) *Evaluation of Methane Detection Devices for Utility Operations,* which focused on the evaluation of new advanced methane-detection devices for walking leak surveys, leak investigations, and stationary remote monitoring. During the project's field evaluation, researchers determined that it would be beneficial to have real-time spatial location information when conducting both leak surveys and leak investigations. That capability could provide information allowing crews to more effectively detect and pinpoint the location of a leak.

For this project, a research team developed a framework to couple high-sensitivity methane/ethane sensors with high-accuracy GNSS systems for on-foot leak investigations and walking surveys.

Deliverables

The project deliverables include:

- A Field-Tested System – Outputting real-time high-accuracy spatial point location of gas detection device methane/ethane readings
- Field Test Results – Including GNSS and gas detection device measurement results, and
- Onsite demonstrations of the field-tested system.

Benefits

Advancements in both high-sensitivity methane/ethane sensors and high-accuracy GNSS devices are driving technology ever smaller and less expensive. It has now become feasible to combine these technologies for use in walking surveys and on-foot leak investigations.

Coupling the readings of sensors with the spatial location capabilities of a high-accuracy GNSS in real time will have clear advantages over current methods. Furthermore, presenting the information on a map via an application will make it possible to improve mapping and tracking of leaks by walking leak survey crews to more effectively and efficiently track and document leak locations. The application can be used to generate a detailed diagram of the methane/ethane concentrations of methane are located, leading the technician to the leak location. The map and concentrations can then be saved to generate forms used for tracking and repair crews to document that the leak has been fixed.

System field testing performed with the breadcrumb application.

All the information collected during the leak surveys and investigations can be stored for later use and analysis by others, helping resolve any ambiguities with leak investigations.

Technical Concept & Approach

Activities included:

- An evaluation of a system that can pair data from an approved gas detection device with a high-accuracy GNSS system
- An evaluation of the ability to visualize the information in real time
- Simulated leak testing of the developed system, and
- Field testing of the developed system on simulated leaks.

Results

In 2020, the project team was successful in performing the initial evaluation of a walking leak survey solution. The goal was to become more familiar with the survey, laying the foundation for a more advanced and comprehensive testing plan to be developed.

Researchers performed this preliminary assessment on a leak-survey "breadcrumb" application since the operating-system version was still in development. To test the capabilities of the breadcrumb application (which combine the readings of a methane sensor with the high-accuracy data of a GNSS receiver), technicians simulated methane leaks in the field using a 99.99% methane gas cylinder canister. A methane sensor was used alongside a GNSS receiver to support the collection of high-accuracy point location.

The evaluation was conducted in a neighborhood where a replica of a gas system was designed to provide a project area to conduct the testing. A GIS feature layer of this replica gas system was created.

The project team was successful in pairing both the high-accuracy GNSS receiver and methane sensor with the leak survey breadcrumb application on an Android device. Researchers were able to collect breadcrumb records around the entire project area using the breadcrumb application. Once completed, the manufacturer provided a spreadsheet containing the breadcrumb information. Not only does the application collect both the methane-sensor readings and the GNSS spatial location data, it can capture vital information that can be used later for compliance and auditing purposes.

In addition to the breadcrumb application, the manufacture also provided a vast catalog of customizable smart forms built into its platform. This will permit field crews to collect data for various types of gas-related activities while they are also performing a leak survey. Some examples of these forms are: Leak Inspection, Meter and Riser Inspections, Access Detail, Map Revisions, and Pipeline Marker Inspections. All the information collected from these forms links back directly to a utility's GIS system, where it can help drive and manage business processes by providing real-time analytics.

Overall, the leak survey performed well during evaluation activities. Researchers assembled requirements of a leak-survey tracking system from the project's sponsors, mapped out the full requirements, developed a framework to evaluate the solution, and then performed a requirements/technology gap analysis.

The single-system "deep-dive" showed the technology is highly capable, customizable, and useful. This evaluation, however, should only be viewed as an initial step in a comprehensive evaluation of the leak survey tracking technology ecosystem.

A full gap analysis of the leak-survey platform was conducted. To do this, researchers first identified the key components and activities that take place during standard leak surveys and which would apply to any application that is focused on tracking leak surveys. To assist in this effort, investigators reached out to the project sponsors to obtain walking leak survey requirement documentation and assembled a list of more than 90 requirements/activities.

The leak-survey platform performed well during all phases of the evaluations conducted in this project. Developers were able to further develop the platform to a level that could be quite useful for gas utilities by saving time in planning, performing, and reporting leak surveys.

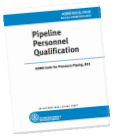
Status

This project is complete. A Final Report was issued in May 2021.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

B31Q Training Documentation Portal



In this project, researchers are implementing a prototype training documentation portal for companies to share training collateral such as videos, documents, and presentations. This project focuses on the training materials associated with Pipeline Personnel Qualification Programs as described in the ASME B31Q standard.

Project Description

Personnel performance and skill competencies heavily impact a gas operator's ability to maintain a safe and reliable system. Industry standards – such as ASME B31Q – specifically document which tasks should only be performed by or supervised by qualified personnel. Furthermore, B31Q documents the specific training and evaluation criteria for workers to become qualified for a task.

Gas industry personnel are interested in sharing the burden of creating training materials. Consequently, a project team formulated the current solution in alignment with the knowledge related to the training requirements within ASME B31Q and technical competencies related to Cloud-based file sharing and web-based application development.

The objective of this project is to maintain a prototype training documentation portal for OTD member companies to share training collateral such as videos, documents, and presentations. This project focuses on the training materials associated with Pipeline Personnel Qualification Programs as described in the ASME B31Q standard.

Deliverables

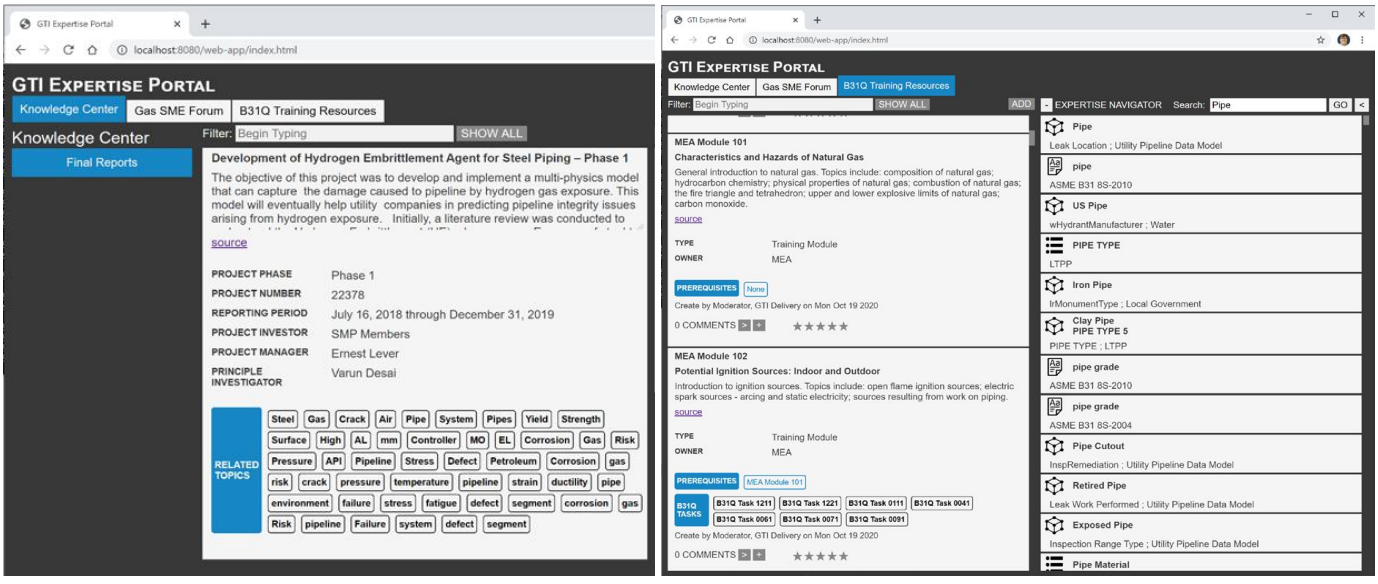
A pilot web-based software application including file-sharing capability and a review and ranking tool will be deployed for use and review.

The project deliverables will include:

- A prototype web-based system
- Software requirements and design documents
- System architecture deployment documents
- Testing scripts and results documentation, and
- Help documentation.

Benefits

Creating materials in support of training programs for operator qualifications can become very time consuming and expensive. Each company can benefit by sharing the cost and burden of creating these training materials for pipeline personnel qualifications documents for inclusion in training programs.



Left: Training resources with live links to the expertise navigator. Right: Expertise navigator showing a topic search and options.

Benefits

Creating materials in support of training programs for operator qualifications can become very time consuming and expensive. Each company can benefit by sharing the cost and burden of creating these training materials for pipeline personnel qualifications documents for inclusion in training programs.

This project will increase access to expertise and knowledge through the development and implementation of a web-based portal. A searchable repository of reports, documents, and other digital assets will be made available through the portal. Additionally, a community forum tailor-made for OTD member companies and their employees will be included in the expertise portal. Knowledge assets will be related to a set of conceptual tags specific to gas industry language, making finding material and related documents easier. These tags will encourage the greater discovery of searched material as well as laterally and hierarchically associated documents.

Technical Concept & Approach

Specific tasks include:

- **Requirements Analysis**

  The project team created a specific list of features and characteristics the B31Q documentation portal system must possess. The requirements include functionality, usability, reliability, performance, and supportability related to sharing files and allowing the community to rank and review the quality of the materials.

- **File Sharing Design and Development**

  Researchers designed and developed the central technology mechanism for uploading and downloading files.

- **Review and Ranking Design and Development**

  The materials on the portal will be curated by the community. In this task, researchers will design and develop the technology components for allowing others to rank the quality of uploaded material, such as a five-star system, and write a description of the materials, such as a review system.

- **System Testing and Rework**

  This task includes creating test-case documentation based on the requirements and design documentation developed in earlier tasks. The test cases will exercise each function, service, and design element as a holistic system. The purpose is to ensure that the system operates as intended after all components are assembled. The project team will execute each test case and record the actual results of the test.

- **Prototype Deployment and Support**

  The prototype system created during this project phase will be deployed to a Cloud-based computer environment where companies may access the system with a companywide user profile. Help documentation for the system will be created during this task.

Results

In 2020, the project team finalized project resource commitments and re-aligned the project workflow with industry best practices. Software was investigated and appeared to supply the needed functionality to tag the final report documents semantically. The development environment for creating the software was constructed and configured.

A final set of requirements was collected from project sponsors and merged into the existing set of requirements.

Researchers finalized all software development. All Phase 1 requirements were manifested as working software features and the software was tested. Testing scripts were edited to their final versions, and a first pass was made to prove their validity. The development system code and databases were deployed to the test and demonstration environment.

In 2021, all software testing was completed and researchers corrected any discovered bugs during testing. A series of training and help videos were created showing how to use the specific functions of the software. These videos were distributed via the OTD Projects website and an email was sent to each project sponsor containing information for accessing the web application and training materials. A kick-off meeting was also held to present these same materials and to answer any questions. The website and support email are being monitored for activity and help requests.

Status

The project team continues to monitor user activity and support user engagement.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Augmented Reality Technology Evaluation

In this project, researchers evaluated, compared, and cataloged existing augmented reality (AR) applications and standalone devices on various mobile platforms. Research results will provide information to make informed decisions to select AR software and devices for the purpose of visualizing a utility's gas infrastructure.

Project Description

Augmented reality (AR) technology provides an efficient and improved ability to visualize and interact with the natural gas infrastructure. AR technology overlays holographic images of the gas system or other information using a mixed-reality device, tablet, or smartphone. The user can visually see the asset overlaid on the real world through the device. This allows people in the field to visualize the gas system as it is buried underground.

In recent years, researchers explored new computing platforms that aim to change how data collection occurs and the process used in the field. As a standalone device, these platforms can provide a powerful user experience. When paired with the right application, a user can interact with a gas utility's GIS data in the field.

This project involved the evaluation of existing AR applications and standalone devices on various mobile platforms. The results of this evaluation will provide information to help make informed decisions when selecting AR software and devices for the purpose of visualizing a utility's gas infrastructure.

Deliverables

Researchers provided detailed documentation in the form of a report for the AR systems that are evaluated. The report compares and contrasts specific functionality and integration for each of the AR systems evaluated.

The project team also demonstrated the different AR platforms to provide a hands-on experience for OTD members.

Benefits

Paired with other computing systems, work-management systems, and asset-management systems, visual-based computing platforms can provide many benefits to utilities and their customers, including advancing the safety, usefulness, and accuracy of gas-asset information when incorporated into gas utility technology programs.

Many applications and devices now exist to provide the ability to view the gas system in AR; however, not all of the applications offer the same access to the utility GIS data.

Various platforms offer real-time access and direct integration with mapping services or other platforms. In order to make informed decisions, it is important to understand the capabilities that exist within different applications and devices.

AR technology provides additional situational awareness in that users are connected with utility geographic information system (GIS) data and can see attribute data and other information linked in the GIS.

Technical Concept & Approach

Specific tasks included:

- Catalog/Inventory Development
- Hardware/Software Capabilities
- GIS/System Integration, and
- Demonstrations.

Results

In 2020, the research team identified software and hardware for evaluation. Once the AR platforms were identified, a project team representative began reaching out to the AR vendors to purchase both hardware devices and software licenses, as well as to schedule training sessions.

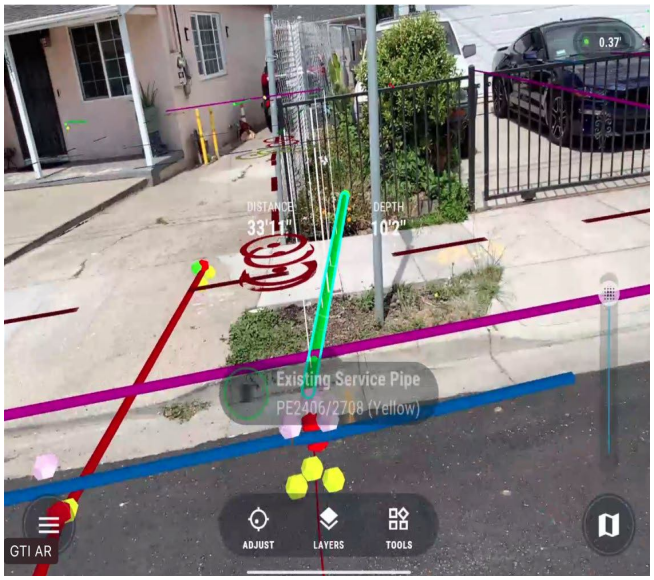
The project team coordinated training sessions with two providers to begin the self-evaluation process of their AR platforms. Researchers laid pipe and gas features (stick-pipe couplings, end caps, tees, and reducers) in a trench to create a replica gas system. This replica gas system was then captured using a high-accuracy satellite receiver, and converted into a GIS feature surface layer. The project team was able to run through several of the use cases.

Researchers also finalized a draft version of the inventory matrix catalog. This comparative matrix can be used as a reference guide for project sponsors moving forward to assist them during their AR selection process. Listed in this document are some criteria identified through past AR projects as essential factors to consider when selecting an AR platform (both hardware and software).

In 2021, the project team and a major utility sponsor to set up the utility's data to be used during a pilot project. Efforts were made to determine the specific attribute information and symbology the company wanted to see and configured both AR software applications' environments (vGIS and Argis) according to those specifications. Researchers developed an AR Pilot Project Information Packet various support documentation information. This information includes a list of the hardware equipment (electronic devices and survey equipment), passwords, software applications to be used, and a Quick Start Workflow/User Guide for each software solution to help walk a user through the software set-up.

The project team developed an AR Pilot Project Feedback Survey to gather feedback and comments from project sponsors regarding their experience with the AR software applications and hardware devices used during this pilot project.

In addition to evaluating the standard augmented reality projection capabilities of vGIS, researchers were able to demonstrate reality-capture functionality, which allows a user to capture a scanned image using their application on any device.



A series of pilot projects was conducted with two sponsors within their respective service areas.

One of the main deliverables from this project is an inventory matrix comparing various AR software applications and hardware devices to each other based upon several key criteria. This matrix can serve as a baseline for OTD member companies to use during their own AR vendor-selection process. The criteria in the matrix ranges from price and platform to operating system requirements and GIS integration and is detailed within this report.

Status

This project was completed in 2021 with the issuance of a Final Report was issued in November.

As exhibited during this project, as well as previous AR efforts, AR technology continues to demonstrate its value within the gas industry as an important tool that can aid field operations. However, to take full advantage of this technology, gas utilities need to understand further how best to integrate it within their company.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Regulatory Compliant Smart Forms

In this project, researchers developed electronic smart forms to improve the process in which natural gas operators satisfy the current requirements for pipeline safety regulations. Smart forms can improve the efficiency, quality, and method in which information is collected by in-field technicians and inspectors.

Project Description

Data collection, inspections, and regulatory compliance activities for managing system integrity are among the most important activities conducted on a routine basis at all gas utilities. As such, significant effort has been spent on developing paper-based forms to collect the right data for each instance. This project involved the concept of developing a template library and the use of Survey123 from Esri.

In 2017, the U.S. Department of Transportation's Pipelines and Hazardous Materials Safety Administration (PHMSA) released a manual that provides best practices and guidance for operators of small natural gas systems. Within this manual, PHMSA designed sample forms that target non-technically trained personnel who operate a master meter system. In this project, a research team identified which of these forms are most commonly used and beneficial to the natural gas industry, focusing on small gas operators. The project team then converted these forms to the Survey123 smart form template to make available to be downloaded from Esri's Survey123 Connect template library.

Using the template library provides a starting point for gas utilities to enhance and inherently add a spatial component to their data collection activities.

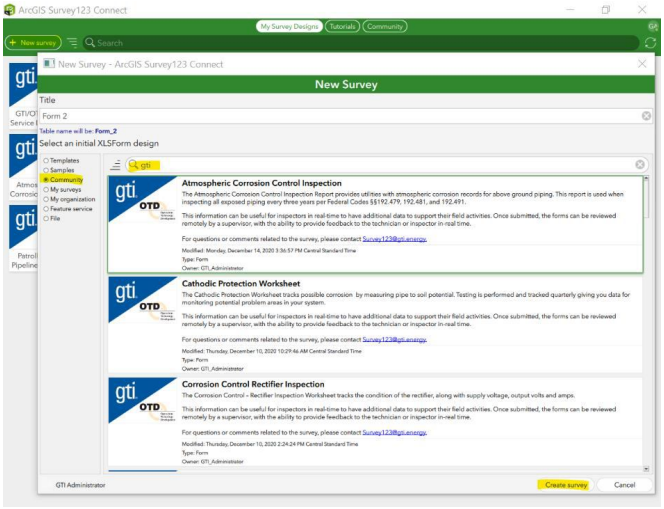
Deliverables

This project produced the following deliverables:

- Survey123 Template Library
- Documentation for each smart form included in the library
- Smart form demonstration as a recorded video/ PowerPoint
- Final Report, and
- Webinar.

Benefits

Developing standardized regulatory compliant smart form templates and aggregating them within a template library allows gas utilities to save time, collect data in a standardized format, and establish parity across utilities for data collection. In addition, these smart-form templates will ensure that the current minimum requirements and standards for pipeline safety regulations and maintenance compliance are met. This will minimize risk by helping to ensure that the



Where to find and download Regulatory Compliant Smart Forms in Survey123 Connect.

appropriate data is being collected, while also increasing productivity by enabling gas utilities to quickly start electronic data collection.

These benefits include: removing the reliance on paper forms, improving the overall process for completing the forms, organizing and structuring the submitted data into a backend database, enabling real-time data collection which can feed real-time system analytics and visualization, and collecting high-accuracy spatial location information (latitudinal and longitudinal coordinates).

The inherent capability of Survey123 to collect a spatial location of data collected in the field can also benefit utilities by improving accuracy of spatial information, and the ability to use the GIS for exposing patterns in results gathered from field data collection.

Technical Concept & Approach

This project included interacting directly with Esri to continue building the gas industry template library used for hosting the smart forms and providing access to gas utilities.

The project team converted as many forms from the PHMSA small operators guide as possible. The selected forms are converted into Survey123's digital data collection format. Additionally, where budget allowed, the project team used internal subject matter expertise to validate these forms, making sure that they capture and incorporate the requirements necessary to satisfy the needs of the gas-related field activity they are addressing.

Results

In this project, a research team established a template library containing a catalog of standardized regulatory compliant smart forms, explicitly designed for the natural gas industry. The vision for the Survey123 Gas Template Library is to serve as a repository of standardized, gas-related field data collection forms publicly available for download. The goal is to help provide a collaborative platform to foster the sharing of these easy-to-use and quick-to-deploy digital data collection forms. These regulatory compliance-based forms are customizable, so they can be specified to meet a gas utility's specific needs and satisfy its regulatory requirements.

Additionally, researchers built a web-based application using Esri's Experience Builder and StoryMap applications to highlight the entire catalog of gas templates publicly available for download through Survey123 Connect.

"As we are moving away from a paper-based data-gathering environment, the timing of the Smart Forms has been perfect. We have seen several benefits already, including saving us time and providing a network where we can share more ideas and suggestions."

- Girish Ranade
Manager, Operations System Support
Washington Gas

Gas Technology Institute is hosting the library through its web-based application Experience Builder. Using this platform highlights the entire catalog of gas templates while also providing gas utilities with a one-stop shop to learn more about every form in the catalog. Forms are grouped into four categories: Data Collection, Inspection, Installation/ Repair, and Risk Assessment.

Status

This project is complete. A Final Report was issued in February 2021.

Researchers plan to build upon the current catalog of Survey123 regulatory complaint smart forms developing more forms based upon requested use cases or desired smart-form functionality. GTI will solicit feedback from OTD and other funding organizations based upon the gas industry's needs.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Expertise Portal and Forum

In this project, researchers are developing a web-based portal to access natural gas industry expertise and knowledge. A searchable repository of reports, documents, and other digital assets will be made available through the portal.

Project Description

The natural gas industry is calling for a better system to help new and existing gas workers engage the large breadth of knowledge resources available. In response, this project focuses on increasing access to expertise and knowledge through the development and implementation of a web-based portal. A searchable repository of reports, documents, and other digital assets will be made available through the portal. Additionally, a community forum tailor-made for OTD member companies and their employees will be included in the expertise portal.

Knowledge assets will be related to a set of conceptual tags specific to gas industry language, making finding material and related documents easy. These tags will encourage greater discovery of searched material as well as laterally and hierarchically related documents.

The technologies necessary to implement the expertise portal are well understood. Additionally, the project team has experience in implementing each of the technologies required.

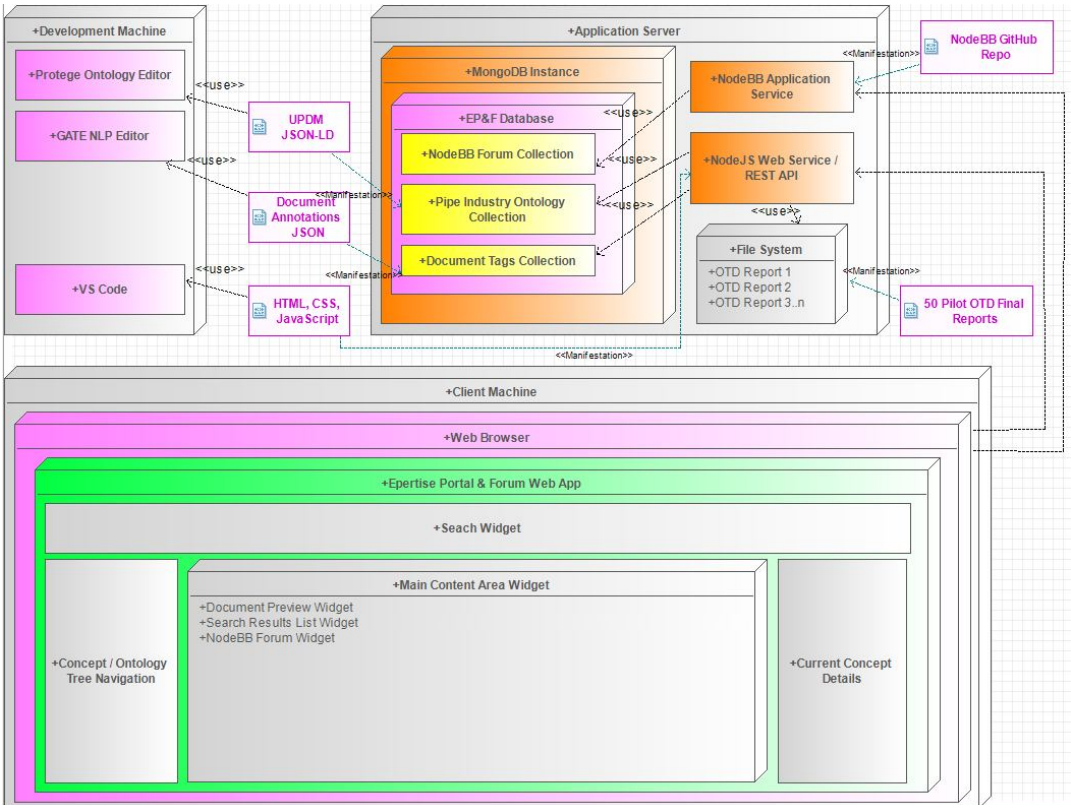
The key research question and challenge for this project is the creation of Natural Language Processing (NLP) resources. These will be tailor-made for gas industry-specific language.

Deliverables

A pilot web-based software application including a community forum and a document search function will be created.

The project deliverables will include:

- A prototype web-based system
- Software requirements and design documents
- System architecture deployment documents



The project's technology architecture plan.

- Custom gas industry semantic ontology
- Custom gas industry NLP processing resources
- Testing scripts and results documentation, and
- Help documentation.

Benefits

This project encompasses several sub-disciplines, including chemistry, physics, metallurgy, mechanical engineering, electrical engineering, information technology and communications, business operations, safety engineering and control, construction, legal, regulation, and more. A gas operations employee will benefit from easier access to a cache of industry knowledge and expertise by having a forum to interact with industry experts in a web-based environment.

Technical Concept & Approach

The fully-featured web portal will be developed and implemented in a series of three project phases.

Phase 1 identifies a suitable information technology platform to support the online web portal. Additionally, a novel approach for automatically tagging digital documents will be created. The new tagging approach will involve creating new NLP token evaluation engines specifically tuned to capture gas industry language. Fifty OTD Final Reports will be processed and deployed on the knowledge portal as a pilot implementation.

Phase 2 continues development of the NLP evaluation engines to include additional types of documents such as technical tables and Code of Federal Rule Structures and Standards documents. Additional documents will be tagged through the NLP application and deployed to the web-based portal.

Phase 3 will finalize all development of the NLP evaluation engines and web-technology deployment.

The project team will create a specific list of features and characteristics the expertise portal system must possess. The requirements will include functionality, usability, reliability, performance, and supportability. The entire list of requirements will be subdivided into the three planned project phases.

A system design will be created that describes a system capable of realizing the required features. The design models will include use cases that describe the user's interaction within the system functions, a deployment model that describes each hardware and software component within their communication channels, and a set of screen mockups which provide a visual layout of the user interface.

System development activities include deploying databases, web services, and forum software services. Customer software code to manifest the web page and communications with the database will be created. As part of this project, quality-control measures, unit testing, and integration testing will be conducted.

Test cases will exercise each function, service, and design element as a holistic system. The purpose is to make sure the system operates as intended after all components are assembled.

Results

In 2020, the project team finalized project resource commitments and re-aligned the project workflow with industry best practices. Software was investigated and appeared to supply the needed functionality to tag the final report documents semantically. The development environment for creating the software was constructed and configured.

A final set of requirements was collected from project sponsors and merged into the existing set of requirements.

Researchers finalized all software development. All Phase 1 requirements were manifested as working software features and the software was tested. Testing scripts were edited to their final versions, and a first pass was made to prove their validity. The development system code and databases were deployed to the test and demonstration environment.

In 2021, all software testing was completed and researchers corrected any discovered bugs during testing. A series of training and help videos were created showing how to use the specific functions of the software. These videos were distributed via the OTD Projects website and an email was sent to each project sponsor containing information for accessing the web application and training materials. A kick-off meeting was also held to present these same materials and to answer any questions. The website and support email are being monitored for activity and help requests.

Status

The project team continues to monitor user activity and support user engagement.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Automations for Tracking and Traceability

The objective of this project is to improve upon data-collection techniques used for tracking and traceability. By automating the data-collection process through digital-scanning techniques, field crews can remain safe outside of the trench and allow the scanner to capture the natural gas assets.

Project Description

In the natural gas industry, standard data-collection methods often require the user to enter a trench with a high-accuracy Global Navigation Satellite System (GNSS) device to collect each asset as they navigate around the pipe. The need to enter the trench could be avoided by having an automated process to collect the data via a handheld, truck-, or cart-driven device. By relying on a one-pass system, a digital scan can occur in just a few minutes, leaving the heavy lifting to post-processing tasks on the computer back in the office.

In addition to scanning and converting data into a geographic information system (GIS), these scans will also provide a historical digital twin. Users who have questions will be able to recall the scan and visualize the assets that were installed before backfilling.

The device will reduce the technical knowledge required to collect traceability data. This automation will ensure that the device is connected to the appropriate high-accuracy GNSS source and eliminate the need for tedious additional tools (e.g. barcode scanners, poles, and tablets used for traceability data collection).

The objective for this project is to automate the data-collection process through digital-scanning techniques, such as LiDAR (Light Detection and Ranging) and high-resolution photography.

These digital twin scans can be stored for future reference and can also be converted to GIS features with high accuracy. Data conversion can take place using LiDAR point clouds and image recognition to accurately extract gas assets with very little human intervention and error.

Deliverables

- Field Testing Results – including photos, imagery, LiDAR point cloud, and GIS data
- Documentation of data workflow, including project set-up, data collection, data processing, and results, and
- A Final Report.

Benefits

Data collection using automated techniques not only keeps people safe, but will also expedite the recording process of the natural gas infrastructure.

The development of an appropriate data-collection device will reduce the technical knowledge required to collect traceability data.

This automation will ensure that the device is connected to the appropriate high-accuracy GNSS source and eliminate the need for additional tools.

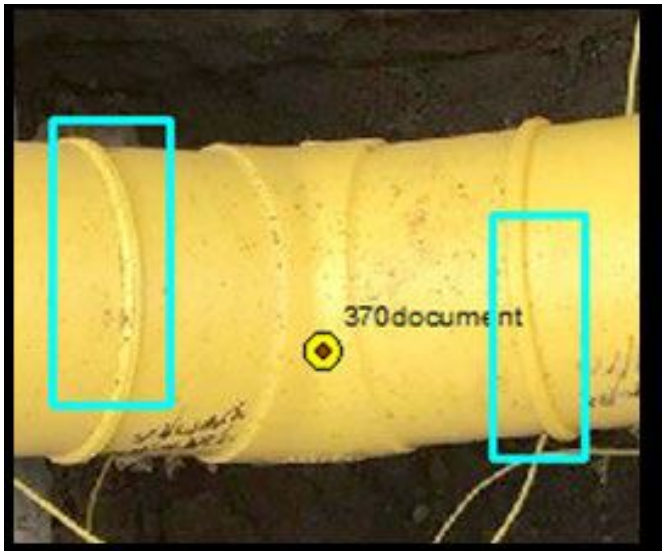
Technical Concept & Approach

In this project, researchers and a manufacturer are making efforts to enhance the company's product by extracting and mapping a natural gas system for distribution-sized assets.

Specific activities include:

- **Technology Implementation**

  The project team will design the workflow of scanning, identifying, and mapping natural gas distribution-sized assets and review the most efficient data-collection processes.



Multiple butt fusions being detected and extracted to GIS features from a single image.

Fully constructed pushcart with the scanner attached.

A cloud-server environment will be created to handle the scanned data and post-processing.

The team will research and test an image-detection platform for identifying and decoding barcodes. In addition, an alternative method of collecting barcode information during the field-scanning process will be investigated.

- **Technology Field Testing**

  The project team will establish a testing site and develop a testing matrix for evaluating data-collection quality.

Results

In 2019, researchers initiated a review of different methodologies for capturing digital twin datasets from various LIDAR/photography-based scanners. For the project, an area was excavated to replicate an open trench setting.

In 2020, researchers reviewed potential open-source software for object detection within images. The project team also began research on motorized push carts that could allow for easier scanning in distribution-type use cases. The device of interest is attached to a metal arm that cantilevers off the side of a truck. The manufacturer also created an automated process for migrating digital scans into GIS data. The core of the company's activities has been on larger-diameter pipe so far, but smaller-sized pipe (i.e., two and four inches in diameter) is in-line with the current business model.

In 2021, the pushcart scanner mount design was completed. In March, researchers received the scanner and performed scans in a small open trench using the electric pushcart. The project team also continued to work on creating a trained dataset of butt fusions based on images provided by a project sponsor. The butt fusions were tagged in more than 800 pictures and then used for training a model for object detection and extraction.

Multiple scans were collected on approximately 500 feet of newly installed four-inch steel pipe. In addition to these scans, multiple scans were performed on two- and four-inch pipes in the existing open trench as well as on the ground outside of the trench. Emphasis was placed on testing the height of the camera to obtain the proper resolution needed to detect the fusions and bar-codes in the scanned images.

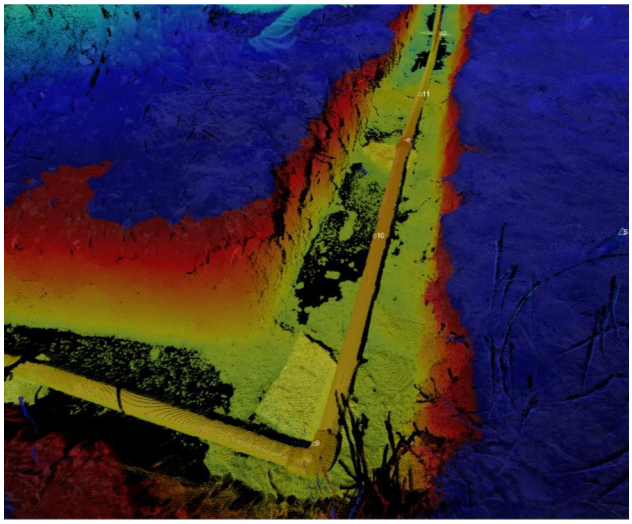
Sponsor outreach was initiated in search of additional imagery to add to the object-detection library.

Researchers continued to test the accuracy of the object-detection model against various imagery datasets. A new filtering option was added to the existing model to reduce the duplication of features extracted upon detection.

Status

Current activities include configuring a backend data server for storing scanning results and continuing to review object-detection software for use within this project.

Researchers are reviewing potential imagery sources for use in the object-detection model.



The goal of this project is to provide a digital twin for utilities to revisit underground work after backfill. This will improve field-crew safety (by alleviating the extra effort to enter the trench to collect data)

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Aboveground Service Tee Identification and 3D Mapping

In this project, researchers are investigating an aboveground three-dimensional electromagnetic technology that has been proven in defense applications of locating subsurface, metallic infrastructure. The technology would be used to define distinct fingerprints of service tees to distinguish between other subsurface features.

Project Description

Improved subsurface locating processes represent a technology gap that has no single solution. However, tools have been proven in locating buried munitions that have unique "fingerprints," distinguishing specific objects from other nearby metallic features. This same technology can be used to identify the cutter tool located within service tees through enhanced algorithms, identifying unique signatures to validate the structure and distinguish it from other surrounding objects.

A preliminary demonstration was conducted to test the viability of this concept. The results that came back were very promising, and additional tasks to enhance the algorithms and unique fingerprints of these objects can take proof of concept into commercialization.

APEX is an advanced system for characterizing buried metal objects.

The aboveground three-dimensional electromagnetic (3DEM) technology was proven in defense applications for locating subsurface, metallic infrastructure. In this project, the 3DEM technology would be used to define distinct fingerprints of service tees.

Deliverables

Deliverables include: a testing report, a field demonstration report, and the final results and webinar.

Benefits

Knowing exact locations of service tees – especially in three dimensions – has been a challenge for utilities. While many utilities have been continuously improving their processes to capture high-accuracy locations of newly installed features, this doesn't address the existing pipe in the ground.

Plastic pipe is particularly challenging to locate. According to the Common Ground Alliance 2015 DIRT report, improperly located or undetected subsurface utilities resulted in 1,906 injuries, 421 fatalities, and $1.7 billion in damages over 20 years. Most locating technology cannot accurately detect plastic pipe. Knowing precise locations of buried infrastructure can reduce injuries and damage, saving money and lives.

Technical Concept & Approach

Specific project tasks include:

- **Signature Classification Enhancement**

  Researchers will identify the various types of service tees that are used in the field, prioritizing the most commonly used equipment, and enhancing the 3DEM tools and software to enable proper signature classification of those components.

- **Testing**

  In a controlled setting, tools will be tested to ensure consistent and repeatable results from various depths and orientations.

- **Demonstration**

  Tools will be demonstrated in the field with at least one utility. The results will be documented, including any enhancements needed from the field demonstration.

Results

In early 2021, a detailed project plan was put in place, and a variety of information about service tees was collected and analyzed by the project team. A formal survey was sent out to the sponsors and subject matter experts for input into the characteristics of the types of service tees that should be considered for testing, as well as the variables that would be important to test.

A manufacturer involved in the project developed several test fixtures that will be used for testing the service tees. Some preliminary testing and data collection occurred.

Efforts focused on the Signature Classification Enhancements task. This task will require the implementation of test fixtures to acquire controlled 3DEM data over a variety of service tees.

A 3DEM sensor known as the APEX is an advanced electromagnetic induction sensor that generates pulse-induction magnetic fields from three approximately orthogonal transmitter coils. As the APEX sensor is pushed along the ground, the transmitter fields polarize buried metal objects along the three principal axes, creating eddy currents that decay with time around each axis of the object. An array of receiver coils located within the APEX sensor measures the decay of these eddy current secondary magnetic fields and enables estimation of the object's electromagnetic "polarizabilities." These polarizabilities define how the object will respond to the impinging magnetic fields from the transmitters and they correspond to the object's size and shape. In the case of a service tee, which is an asymmetric object, the three principal polarizabilities are different for each axis.

Because the electromagnetic polarizabilities are intrinsic and unique for each object, they can be used as "fingerprints" to identify a class of object. Researchers are acquiring APEX 3DEM data over a variety of service tees as well as other typical subsurface utility objects to demonstrate that service tees can be correctly identified based on their electromagnetic fingerprint and distinguished from other common underground metal objects.

A test stand allows for controlled, static measurements with the APEX sensor placed above the service tee samples. The service tees can be placed at different lateral offsets, orientations, and depths below the sensor to evaluate the system performance and sensitivity to these variables

The fused tee and pipe materials will be tested to determine if there is any signature change between un-fused tees (and thus not installed or impeded by other materials) and fused ones. Researchers will also investigate how additional asset types such as marker balls, tracer wire, and other locating aides may introduce additional information into the overall dataset, which may help users in the data interpretation and identification process.

To date, the project team received a catalog of 16 service tees, ranging in diameter sizes, manufacturers, and fusion types.

Libraries were made for each of the items in the initial shipment. Signatures varied widely for the different tees and indicate that library classification may be an effective way to accurately detect and identify buried tees.

Status

The following activities are scheduled for execution:

- Continue coordination with sponsors to receive additional service tees for testing
- Continue to catalog and fuse additional donated service tees
- Completion of library signature data collection for remaining tee samples, and
- Perform depth performance testing to determine maximum identification depth for each service tee (will be performed in the test stand).

Tees will be tested to a full range of depths (i.e., until no signal is obtained above the noise floor) to ensure maximum depth analysis can be performed. A library match metric will be used to quantify the classification performance at each depth.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Enhancing Locating Technologies with Better Accuracy for Underground Pipelines

Research in this project focuses on increasing the accuracy and availability of horizontal and vertical pipeline-location information to improve the safety and integrity of underground natural gas pipelines. The solution is based on enhancing and adapting above-ground 3D electromagnetic detection technology.

Project Description

Accurately locating underground gas facilities depends on many variables, including the depth, type of ground cover, pipe material, pipe size, soil moisture, proper operations of equipment, proximity to other buried facilities, and other factors. No single tool can address every combination of these variables, which makes it a complex issue to address.

Previous projects related to buried pipe, utility line, and infrastructure technology generally either consisted of an assessment of currently available methods or have attempted to exploit multiple methods via associated data-fusion techniques. In contrast to past efforts, this project focuses on advanced 3D electromagnetic (EM) methods, which were proven effective during related parallel efforts sponsored by the U.S. Department of Defense. These technologies offer a substantial improvement in pipe detection and localization as compared to mainstream one-dimensional sensors through the use of three-axis transmitters. Additionally, the full 3D response of the target is captured via an array of triaxial receivers, providing a vast improvement in resolution compared to mainstream sensors that record only a single axis receiver response.

The solution is based on enhancing and adapting above-ground large-standoff 3D EM detection technology and supplementing the technology with an in-pipe mechanism to focus on congested areas and plastic materials. The combined solution will address most of the in-field conditions, including varying pipeline material, depth, and surface cover. The improved tools will provide access to the 3D data in near real time.

Deliverables

The deliverables include:

- Stakeholder Requirements Document
- Baseline Performance Document
- System Optimization Document, and
- System Performance Document.

Benefits

The key benefits of this solution include damage prevention through accurately locating buried facilities and increasing the ability to maintain higher-accuracy mapping data in three dimensions. This data helps to serve not only the locating and construction processes but in many future activities that can use this data to integrate into other systems, providing exceptional value and knowledge of their infrastructure to gas operators.

Technical Concept & Approach

The richness of the data collected from an array of three-axis receivers along with the 3D illumination enabled by a set of three-axis transmitters form the basis for this project.

Additionally, software was developed specifically for modeling subsurface pipes, exploiting the predictable geometries of these cylindrical targets and their associated EM responses to full illumination.

Researchers will set a baseline estimate of the capabilities and performance of existing technology as it performs before optimization.

Main goals are for the project team to: enhance the 3D EM hardware to optimize the range (depth) and 3D positional accuracy of locating natural gas system components.

The research team will conduct a minimum of a six-month field test at sites volunteered by California utilities to demonstrate the improved technology under a variety of field conditions.

Researchers will develop a plan to make the knowledge gained, experimental results, and lessons learned available to the public and key decision makers.

A plan will also be developed to determine the steps needed to lead to the manufacturing of technologies developed in this project or to the commercialization of the project's results.

Results

In 2020, a natural gas pipe test area was established and tests were performed on five buried pipe segments ranging in length from 10 to 21 feet and in diameter from two to six inches. This site facilitates rapid and straightforward access to a relevant target set. Initial assessments of pipe-location accuracy were made by analyzing the test data. Processing included review and assessment of collected data including statistical assessment of signal and noise levels.

Advancements in streamlined and automated processing of data were achieved, which established a foundational workflow highly advantageous to envisioned applications. An existing algorithm for forward modeling of pipe signatures was implemented in the workflow.

In 2021, the project team developed a Stakeholder Requirements Documents based on a survey with inputs from 12 gas utilities across the U.S. Researchers also finalized three locate technologies for the baseline performance evaluation.

The research team continued finalizing and organizing activities required to perform the Baseline Evaluation of Existing Technology, including ordering materials for the pipe farm and summarizing a draft assessing two commercial EM locating devices.

The team initiated the process of acquiring and summarizing the current best practices for two sponsors for incorporating into the test plan. A gantry system to support large standoff measurements of test pipes was built. The gantry is a non-metallic test fixture that spans a 30-foot testbed. This system allows for the simulation of dynamic overpass of various pipe configurations at effective depths of more than two meters.

Researchers performed a high-accuracy spatial location survey on the pipe system in the trench prior to backfill. The high-accuracy survey will be used to establish the true horizontal and vertical positioning of the pipe for the baseline evaluation task.

A design improvement in the sensor hardware reduced the receiver preamplifier noise and should enable greater depth of pipe detection, localization, and classification due to the increased signal-to-noise ratio.

The project team submitted two milestone reports to California Energy Commission (CEC): Baseline Performance Document and System Performance Document. The Baseline Performance Document describs the testing and evaluation of three leading non-intrusive commercial off-the-shelf EM sensors. The System Performance Document summarizes the initial performance results of compared to the commercial off-the-shelf EM sensors evaluated.

Several algorithmic changes were implemented to improve 3D positional accuracy. An on-site demonstration of in-pipe mapping and locating technology was conducted.

A multi-target model to mitigate the effects of surface clutter in the pipe farm data set was developed. Proximity of surface or shallow clutter to the pipes creates large EM anomalies. By implementing a model that accounts for clutter sources, it is possible to extract accurate pipe parameters in the presence of clutter. The system has GPS data that are acquired simultaneously with each EM field measurement.

Researchers mobilized the system for a baseline technology assessment. Testing comprised 1.5 days of surveying in the pipe farm.

Status

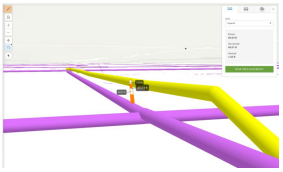
In 2022, the project team continues to optimize data-processing algorithms. The results from testing an in-pipe probe mapping and locating tool are being analyzed.

Pilot demonstrations are being organized.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

3D Visualization Software for Mapping Underground Pipelines and Improving Pipeline Asset Management



For this project, researchers are developing 3D visualization software for mapping underground pipelines and improving pipeline asset management. The technology will provide field operators with digital documentation and surrounding site conditions to help guide the proper procedures being used during an underground pipe utility locate.

Project Description

In the natural gas industry, inaccurate or insufficient locating practices can lead to a significant number of injuries and considerable costs. Knowing where buried infrastructure is located can aid in mitigating these risks and preventing damages.

In this project, research is focused on the development of 3D visualization software for mapping underground pipelines and improving pipeline asset management. This platform will assist field users in visualizing locate data from a variety of inputs and will be validated with a field demonstration.

To help address the 21% of excavation damages caused by insufficient or inaccurate locating practices, the technology will provide field operators with digital documentation and surrounding site conditions to help guide the proper procedures being used during an underground pipe utility locate.

Researchers will aggregate several existing and proven technologies assembled into one locate technology platform that supports the implementation and adoption of new business processes designed to achieve operational performance improvements.

Deliverables

The deliverables for this project include:

- Business requirements and analysis reports
- Hardware/software interface requirements
- All software and system documentation
- Access to source-code repository
- Testing documentation, and
- Pilot analysis.

Benefits

Visualization software can improve the safety and integrity of underground natural gas pipelines by increasing the accuracy and availability of horizontal and vertical pipeline location information. More accurate locate results will help prevent future excavation incidents where the root cause is inaccurate locate markings or insufficient locate practices.

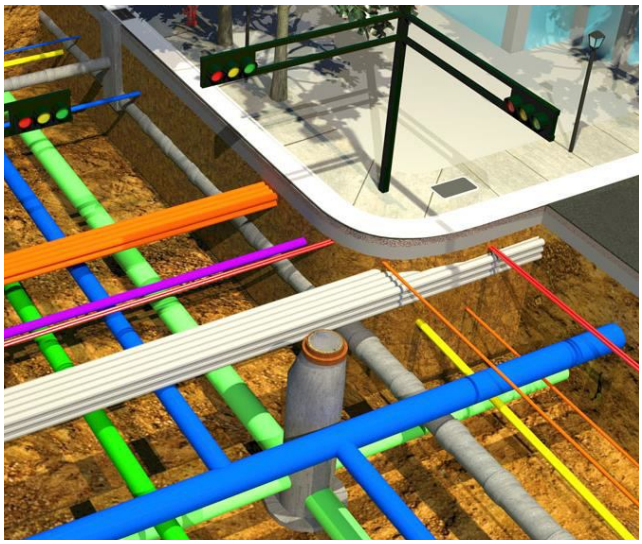
A set of business process models are being created to describe the necessary process improvements an organization must make in order to improve the geospatial accuracy of existing Geographic Information System (GIS) data in both the horizontal and vertical dimensions.

Technical Concept & Approach

Specific project tasks include:

- **Analyze and Evaluate Participating Locate Data Sources**

  This task will determine how to integrate the select data sources and transmit real-time information from the utility-locate tool and GNSS (Global Navigation Satellite System).



- **System Requirements and Design**

  Researchers will develop the requirements of the project expectations and software for the system and use this documentation for auditing and testing.

- **Develop Cloud- and Field-Based Platform Components**

  Researchers will develop the Cloud-based and field-based software that integrates the various data sources into one platform. The platform provides users (both in the field and office) with visualizations of the infrastructure location and metadata.

- **Perform System Testing**

  System testing will be conducted on sample above- and belowground pipe.

- **Pilot Demonstration and Analysis**

  The goal of this task is to conduct a minimum of a six-month field test at sites volunteered by California utilities to demonstrate the improved technology under a variety of field conditions.

- **Evaluation of Project Benefits**

  The project team will complete project benefits questionnaires that provide all key assumptions used to estimate projected benefits, including targeted market sector (e.g., population and geographic location), projected market penetration, baseline and projected energy use and cost, operating conditions, and emission-reduction calculations.

- **Technology/Knowledge**

  The project team will develop a plan to make the knowledge gained, experimental results, and lessons learned available to the public and key decision makers.

- **Production Readiness Plan**

  The goal of this task is to determine the steps that will lead to the commercialization of the project's results.

Results

In 2020, a kickoff call was held with the OTD project sponsors to introduce the project and solicit feedback on utility locator devices and best practices. Meetings were also held one team meeting with two California utilities participating in pilot projects for this project.

Researchers reviewed existing utility locate devices, both electromagnetic (EM) and ground-penetrating radar (GPR), and documented the requirements on field locate best practices. The team also designed components needed for the software application being built under this project.

In 2021, code was migrated from existing applications into the new development environment, securing GIS data from project sponsors to build out requirements for the software application. Additional work included setting up the project development server with the proper applications.

The project team evaluated utility locating devices for their data transmission attributes over Bluetooth. These evaluations led to the beginning stages of data retrieval and conversion into a 3D GIS feature. Researchers also converted existing 2D gas pipeline data from a project sponsor into a backend 3D base map.

The project team and a California-based subcontractor began the process of acquiring and testing two utility locate devices on various gas pipelines originally collected with high-accuracy Global Navigation Satellite System receivers.

Investigators also began building a site conditions entry form for utility field locate traceability documentation. Additional efforts were made to create an in-office web application that would display field locates in 2D and 3D formats from an accessible website. Moreover, the functionality of the two handheld EM locators was tested against high-accuracy utility sponsor's data.

Status

- Researchers continue to develop the in-office web application.
- Utility information is being reviewed and transfered into the enterprise database.
- Implementation efforts on the site conditions survey form within the software application.
- Test data collection and submission from EM devices to new backend GIS data schema.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Mobile Leak-Classification Application

Development activities are under way for a mobile application that allows field crews to collect and enter leak information (concentration, distance from structure, frost conditions, etc.) into a tool, which in real time calculates a leak classification and recommends a course of action.

Project Description

Classifying leaks can be a daunting task for a gas company employee trying to determine the severity of the leaks. The application being developed in this project will complement decision making by the field crew and add consistency in the operation.

As the workforce ages, this application can be a vital tool, assisting younger and less experienced employees as they perform a leak classification by providing them with guidance and support throughout the process. Conversely, this application can also benefit more experienced personnel who have been performing leak classifications for many years. Using the real-time mobile application provides a certainty of a positive outcome.

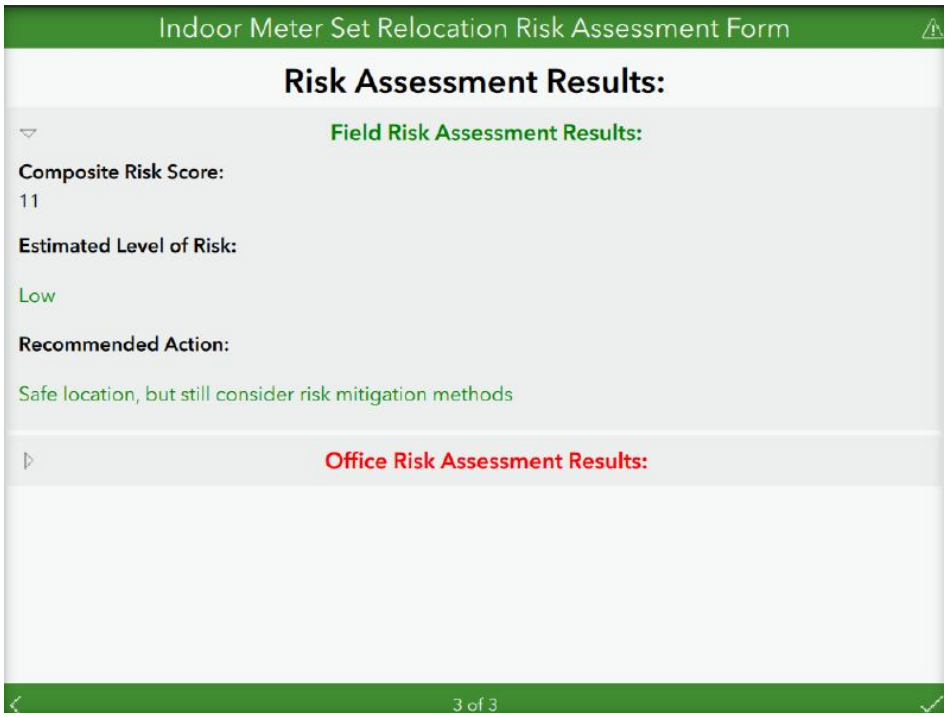
There are always obvious situations where classifying a leak is simple (e.g., gas migrating into a house or sewer) or times where there is no immediate danger. However, even with training and support from guidance manuals, clear-cut situations need to be approached and evaluated with the same consistency across an organization. An electronic tool will help eliminate these inconsistencies by utilizing the preconfigured smart-logic functionality built into the application.

The overall objective for this project is to develop a mobile application allowing field crews to collect and enter leak information (concentration, distance from structure, frost conditions, etc.) into a tool, which, in real time, calculates a leak classification, a recommends a course of action.

Deliverables

The deliverables for this project include:

- A Leak-Classification Guidance Table/Decision-Tree Matrix
- Smart Form checklist for leak-classification requirements
- Leak-Classification Electronic Smart Form in Survey123 Format
- Demonstration on how to download and use the developed Smart Form, and
- Support documentation.



Benefits

Having access to a well-structured and organized set of leak-classification guidelines can significantly improve the consistency by which leaks are evaluated and assessed in the field. Using an electronic Smart Form as this guidance tool can help remove any doubt and lessen uncertainty about classifying a reported leak's severity for field crews.

This mobile application will provide field crews with in-field guidance, walking them through the leak-classification process, improving efficiency, reducing human error, and eliminating bias from the process. The tool can also be customized based upon the specific requirements and leak classifications for each company.

In the field, leak investigators and survey personnel face difficult scenarios while classifying leaks. Irrelevant influencing factors or challenging decisions can lead to variation in processes and produce inconsistent results. A mobile application that guides the field user through recording the correct and complete set of applicable leak-classification factors will encourage uniform processes and consistent results from scenario to scenario.

Since the application calculates a leak grade based on the user's input of actual site conditions, confidence in the results from the field can be trusted and used more accurately due to the elimination of any potential bias from various external circumstances. Additionally, a recommended course of action will be generated in real time, providing field crews and leak managers the ability to manage leaks within a utility's gas system in a more efficient and timely manner in accordance with their own policies and procedures.

Technical Concept & Approach

This project focuses on interacting directly with project sponsors and subject-matter experts to develop a mobile application capable of collecting the required information necessary to perform a classification grading on a reported leak. A Survey123 Smart Form will be created and made available for download.

Based on the leak-classification requirements provided to the project team, criteria for categorizing information collected during the leak-classification process will be identified and outlined in a Leak-Classification Guidance Table/Decision-Tree Matrix. This document will be used to facilitate discussions and refine categories and criteria through brainstorming with project sponsors. Once complete, researchers will host a webinar to present the guidance matrix, Smart Form checklist, and leak-classification requirements documents.

The project team will use the information collected to build the Survey123 Smart Form. Once a final version

of the form is approved, researchers will provide project sponsors with a full demonstration, detailing all the various capabilities and functionality within the form. During the demonstration, the project team will showcase the Gas Template Library, where the form will be made available for download.

Investigators will complete a Final Report detailing the development of the leak-classification form.

Results

In 2021, the following activities were accomplished:

- Identified resources for the project and formed the project team
- Completed contracting for the project
- Held a project kickoff call with OTD sponsors
- Finalized and detailed a project schedule, and
- Designed and distributed a survey to sponsors, soliciting information on various project requirements and supporting information regarding their process for classifying leaks.

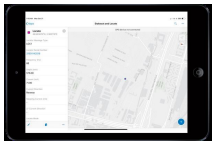
Status

Researchers are defining the criteria that will be used to categorize the information collected during the leak-classification process. This information will be used to develop the Leak-Classification Guidance Table/ Decision-Tree Matrix.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

High-Accuracy Locator Technology Evaluation



Researchers are evaluating emerging capabilities in handheld gas-equipment locating technology, combining high-accuracy global navigation satellite systems, locators, and software to collect location and other meaningful data attributes from the locators.

Project Description

The process of locating and identifying underground assets is an essential aspect of gas utility operations.

Over the years, a significant amount of research was conducted on technologies for locating underground gas pipes and facilities. This is primarily due to the importance of accuracy, technology, and variation in the materials and conditions in which gas assets are buried.

Most recently, OTD 5.17.n, *Survey of Plastic Pipe Locating Technology and Locating Practices,* carried out a research initiative with a multi-pronged approach to assess previous research conducted in 2009. While there has not been a significant technological advancement in the capabilities of locators between 2009 through 2017, the fusion of multiple technologies available in 2020 makes it possible to improve the functionality and workflows by which handheld gas locators are implemented. Using high-accuracy receivers coupled with locators, it is also possible to update horizontal data and collect depth/vertical data unlocking additional capabilities within the geographic information system.

This new project involves an evaluation of emerging capabilities in handheld electro-magnetic (EM) locating equipment, combining high-accuracy global navigation satellite systems (GNSS) and software to collect location and other meaningful data attributes from the locators.

Deliverables

The deliverables for this project include:

- Workflows tested for devices
- Comparison matrix of tested functionality for each selected locator, and
- Spatial accuracy reports for the use of GNSS devices.

Benefits

Improvements in facility-locating technology benefit the gas utility and its customers, primarily in the safety of gas operations.

Increased accuracy and workflows may result in improvements and efficiencies in the locate process and allows the utility operators to record their subsurface asset in a GIS with high-geospatial accuracy. Streamlining these processes will positively impact damage-prevention practices, data quality, and emergency-response capabilities.

A device for evaluation with a high-accuracy real-time kinematic GNSS receiver embedded in the locator itself. This type of receiver is preferable to a GNSS receiver embedded in the display/head of the locator, where it is difficult to have

Improvements being installed and surveyed with a drone at Gas Technology Institute's pipe farm.

Technical Concept & Approach

This project involves the identification, evaluation, and testing of workflows for high-accuracy handheld locating devices for underground gas assets. Researchers are specifically evaluating the potential for improvement in spatial accuracy and improved workflows to enable a more efficient and accurate locating process and capturing the locate data in GIS in real time.

The project identified select locators that satisfy the project's requirements for a high-accuracy GNSS integration, Bluetooth connectivity, and software-based workflows. Also, manufacturer-specific data-capture applications and Cloud-based data repositories are now commonplace and will be included in the evaluation.

Researchers will compare locators for both spatial accuracy and accuracy to locate underground pipe. Consideration regarding the ease of use and the amount of additional equipment necessary for these locators' operation will also be evaluated. Software and workflow for third-party integrations and device-specific applications will be tested and assessed.

Field testing will document spatial accuracy for data collected from the GNSS receiver and locate accuracy of the handheld gas locators. All of the testing data will be compared against a pre-established baseline of 3D-surveyed assets in an open trench that will be buried prior to the testing.

Results

In 2021, researchers started collecting information about locating tools and software applications that will be used for the technology evaluation. Information on vendors from which to procure test instrumentation was also gathered. Requirements sessions were held with project sponsors to discuss important testing variables

Investigators experienced some challenges with setting up and testing/training with some of the acquired technologies and is working with the technology providers on understanding the capabilities, setting requirements, and clarifying the identified issues.

The project team finalized the subject technologies to be evaluated in the project and purchased or rented all of the selected technologies. Onsite testing was arranged with two participating utilities and multiple vendors (approximately 10 participants) for each testing site. Vendors will provide subject matter experts, equipment, software, and any other materials needed for testing.

Researchers also started coordinating with several sponsors to establish test sites for the project. In addition to sponsor test sites, which will focus mainly on plastic assets, improvements to Gas Technology Institute's pipe farm will provide for suitable testing in some scenarios – primarily steel pipe at various depths.

Initial training and preparation was executed for each technology.

Status

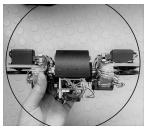
The following activities are scheduled for execution:

- Travel to the two testing sites and perform technology evaluations
- Collect all data, imagery, and other information
- Perform additional testing at if needed, and
- Prepare testing data for analysis.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

PipeRider Tetherless Robot



Researchers are further developing the PipeRider in-line inspection platform by adding an additional level of control in a prototype that will autonomously identify and navigate through pipelines containing tees, bends, and elbows.

Project Description

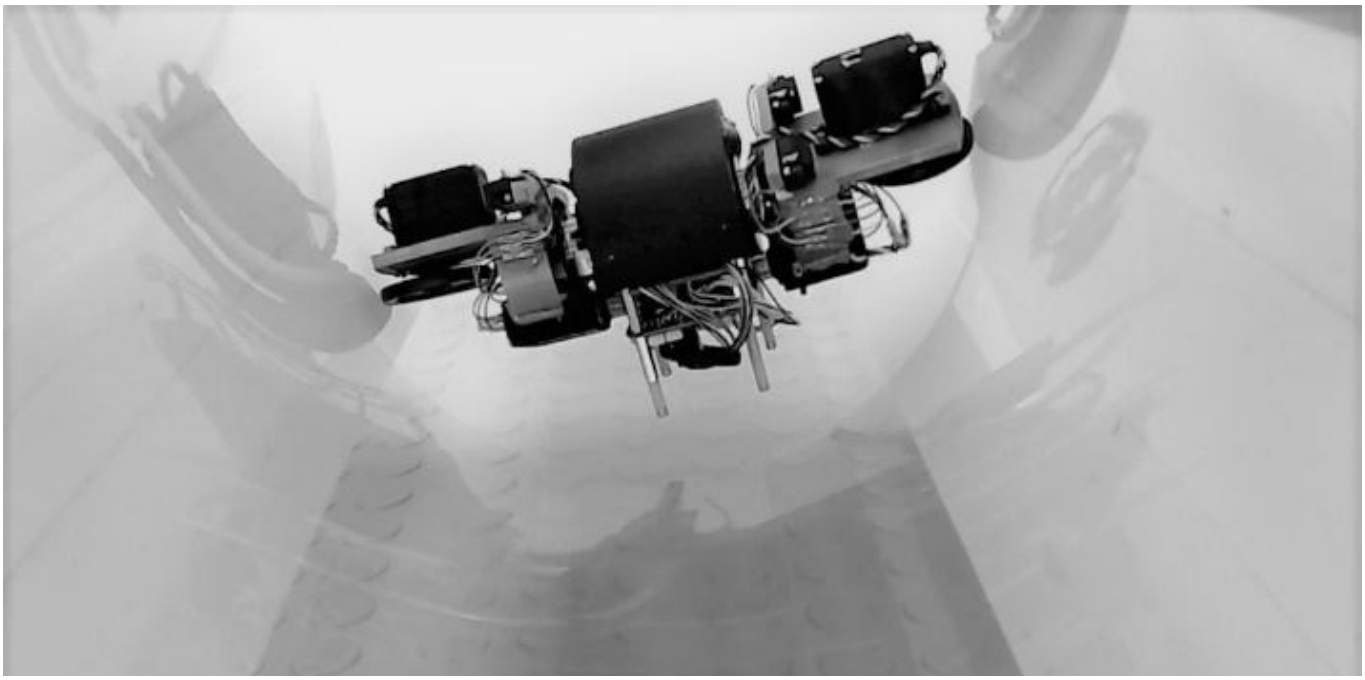
For decades, the natural gas industry has relied on in-line inspection (ILI) devices to assess the integrity of their pipelines. This crucial process helps ensure the safety and reliability of the pipeline infrastructure.

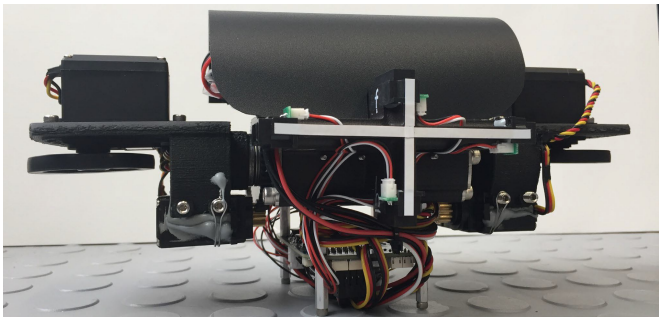
In-line devices are propelled by gas pressure or self-propelled via a tether cord that provides control and power. These tools collect several types of data that support integrity management programs and other aspects of operations. This data (visual, audio, position, pressure, eddy current, magnetic flux leakage, etc.) helps operators identify corrosion and map the infrastructure. Currently, few of these devices provide the ability to make repairs to the infrastructure.

ILI devices provide valuable data, but only in pipeline locations that are accessible. Significant gaps exist in the ability to inspect pipelines that contain tees or sharp bends, or those that are of a diameter smaller than existing ILI devices. Furthermore, many self-propelled ILI devices are limited by the length of their tether.

Many years of research were conducted into tire combinations that are used to move an object through cylindrical pipe walls by pushing against them in the same plane. By rotating the gimbals that hold the tires in opposite directions, a prototype crawler could be made to spiral in the pipe during axial translation. The aviation industry calls this motion "roll," and researchers realized that all of the terminology used for linear and rotational coordinate axes could be applied to a pipe crawler that uses a co-planar two-tire design much like an airplane has a two-wing design. Phrases such as yaw, roll, and pitch are borrowed from the aviation industry because of the parallels in aircraft.

The technology being advanced in this project was granted the first patent for roll control in 2008. At the time, it was purely a mechanical device, relying on a pendulum mechanism to control the gimbal angle. As technology improved, other designs became possible. Two additional patents were granted in 2012 and 2013 for yaw control (which kept the crawler perpendicular to the pipe walls at all times) and for "deploy retract" (which allowed the crawler to be dropped into the pipeline and then unfold its tires and climb the pipe walls into its operating configuration. A pitch control patent protection is pending. The crawler is now called PipeRider because it can "ride" inside the pipe with four degrees of freedom: axial translation, yaw, roll, and pitch.





The tetherless PipeRider now enters its next phase of development – pitch control. Pitch control will give this pipe crawler two critical performance features: 1)the ability to stay aligned with a pipe's center axis regardless of the angle of the pipe underground and 2) the ability to turn a corner when an elbow or tee is encountered. PipeRider would roll to a vertical orientation for a turn in the horizontal plane.

The objective for this project is to build upon the progress developed thus far on the Pipe Rider platform by adding an additional level of control. Successful completion of this project will result in a prototype of PipeRider that will autonomously identify and navigate through pipeline infrastructure containing tees, bends, and elbows after deployment into an open depressurized pipe. Future versions may be deployable in live pipes via drop tubes.

Deliverables

The main project deliverables will be:

- Project communications and presentation materials
- Project Final Report, and
- A sponsor demonstration.

Benefits

The gas industry and its customers would benefit significantly from devices that allow data collection and repair in difficult-to-access segments of the pipeline infrastructure. Collective investment in an autonomous ILI device that can navigate bends and small-radius pipes would significantly increase the ability, speed, and cost-effectiveness of inspecting, assessing, mapping, and potentially repairing the pipeline.

The autonomous nature of PipeRider operation will free up operator time for other critical activities. Cornering ability and untethered operation will allow utilities to inspect and map longer lengths of geometrically challenging pipe without the need for the launch tubes and aboveground infrastructure necessary for conventional ILI devices. Because Pipe Rider can navigate more effectively, it can be inserted into pipeline infrastructure in ideal locations – far from residential structures or in congested areas where permitting may be an issue. Fewer insertions will save operational teams time and reduce customer disruption due to excavations.

Technical Concept & Approach

This project is intended to be a Phase 3 project to add pitch control functionality to the Pipe Rider.

Researchers are conducting the following activities:

- Developing equations of motion for the force needed to rotate Pipe Rider for negotiating pipe elbows or tees
- Using solid modeling to create space inside a main body for new components
- Building a test stand to prove out motor sizing and torque output, and
- Incorporating a new reaction motor into a new functional prototype.

The project team will test pitch control for turning capability in a laboratory environment.

Wiring of the existing controller will be updated and sensors added to detect pitch/plane and pipe walls. A new prototype will be built with yaw + roll + pitch capabilities. Prototype performance will be characterized in testing.

A virtual demonstration of the prototype will be provided to sponsor companies.

Results

In 2021, the the project team continued its research into the ILI market and spoke to customers regarding their current ILI programs and inspection activities.

Status

Researchers are scheduling additional discussions with project sponsors to address the prototype and gather requirements for the device. This feedback will be incorporated into the PipeRider's product roadmap.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Improving HCA Classification Methods

Efforts are being made to improve the accuracy of classifying high-consequence and moderate-consequence pipeline areas through modern data analysis and data sources. The fluctuating variables currently used can potentially change impact areas and expose unnecessary risk to gas utilities and their customers.

Project Description

Conventional methods of conducting population analyses and building potential impact areas have not changed much since their implementation. The current methods utilize U.S. census data can potentially rely on outdated population information. The fluctuating variables can potentially change impact areas and expose unnecessary risk to gas utilities and their customers.

There is a labor-intensive process to identify and calculate impact areas that meet criteria defined by the U.S. Department of Transportations Pipeline and Hazardous Materials Safety Administration (PHMSA). Current PHMSA criteria addresses:

- Twenty or more structures intended for human occupancy
- Buildings housing populations of limited mobility
- Buildings that are hard to evacuate (e.g., nursing homes and schools), and
- Buildings and outside areas occupied by more than 20 people on a specified minimum number of days each year.

In 2019, PHMSA published an update to require new regulations for integrity assessments conducted outside of High-Consequence Areas (HCAs). The regulations have a less-stringent assessment requirement, although they use the same data sources used in calculating HCAs. An HCA is specifically defined as an area where a release of natural gas would adversely impact the health and safety of the affected population. It is the pipeline operators' responsibility to ensure the integrity of the pipeline in the HCA.

Within a Geographic Information System (GIS), it is possible to automate and manipulate variables to efficiently provide robust, up-to-date data for all critical consequence areas. This data can significantly improve situational awareness and provide a holistic benefit to a gas utility's risk profile.

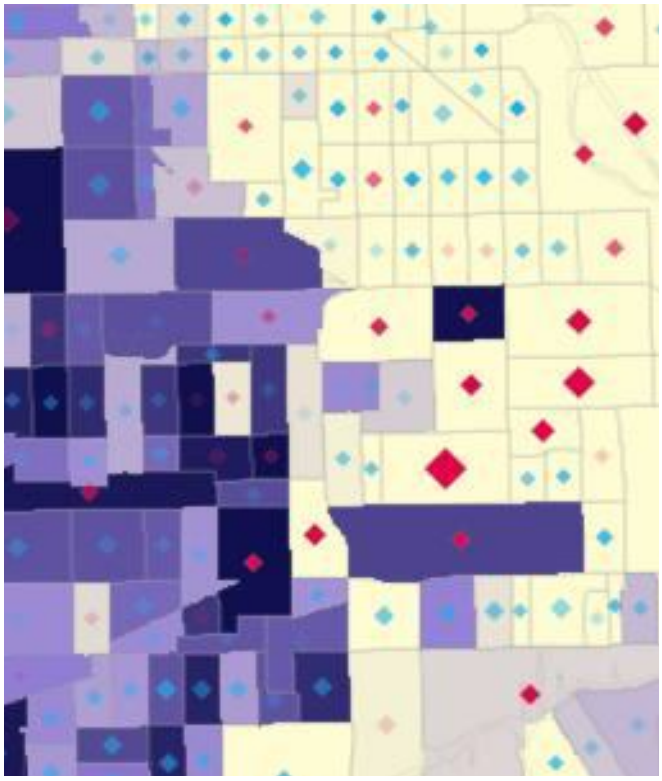
The objective of this project is to improve the accuracy of classifying HCAs and moderate-consequence areas (MCAs) through modern data analysis and data sources.

Deliverables

The deliverables for this project will include:

- Data sets that provide cell-phone data information
- Satellite-imagery data sets to depict changes in the urban landscape
- Algorithms and other information used to automate the quantification of population or building use and size
- Animated time-series graphic showing comparison and analysis of data sources for potential impact radius polygons, and
- A Final Report.

A follow-on phase of this project, based on the effectiveness of the data sources to produce efficient and timely results, may prompt additional discussion with PHMSA.



Updated census data products graphic.

Benefits

Developing the capabilities to leverage more accurate and modern data sources can help:

- Reduce labor hours categorizing new development
- Automate and produce more accurate population estimates
- Add population movement patterns to reinforce or reduce impact areas, and
- Improve emergency-response capabilities through pattern analysis of populations.

Technical Concept & Approach

This project's scope includes an evaluation of the potential of updating the methodology used to create potential impact areas as defined by PHMSA. Through new data sources and data-analysis capabilities, it is possible to update and track changes within human populations and urban landscapes that affect the delineation of consequence areas.

Specific tasks include:

- **Research Cell-Phone and Satellite-Data Options**

  This task will identify and obtain cell-phone data and satellite data. Aspects will include the ability to access data for a given time period, obtain data at a sufficient level of granularity, and review the accuracy of data collected by providers.

- **Identify Data for HCA\MCA**

  This task includes the identification of HCAs and MCAs as defined by the PHMSA guidelines. Sponsor feedback will be collected to find an appropriate area to conduct the comparison and data-collection activities.

- **Data Calculations and Comparison**

  This task will calculate and compare data obtained for the same geographic areas and define a potential impact radius polygon. A time-series analysis will be conducted to determine the extent of change in population and urban development that has occurred.

This analysis will be conducted using GIS software and will result in an animated graphic depicting the results from year to year, including comparison of the results from using different data sets for the analysis.

Results

This project was initiated in 2021 with a review of the HCA and MCA regulations from the PHMSA. Researchers created a list of vendor companies that provide cell-phone and imagery-based change detection services. The project team also identified potential project sponsors for subject-matter expertise discussions.

Project representatives contacted multiple vendors and received multiple demonstrations regarding their products. Additional meetings were conducted to retrieve sample data or examples of results based on a fictitious dataset. The project team utilized this sample dataset to help establish a workflow with the vendors as well as pricing. A project sponsor provided additional information on its HCA and structure-verification processes.

The research team received initial cost estimates from both satellite-based change-detection and cell-phone data providers to use in conjunction with the project's budget. Separate data was acquired sample data from three separate cell-phone providers and reviewed for potential use in the project's proof of concept.

Sample images and a web map example were received from two satellite-based change-detection companies.

Researchers began the initial stages of communication with an internal legal team regarding the proper path to secure services from selected satellite-based change-detection and cell-phone data providers.

Status

The following activities are scheduled for execution:

- Complete non-disclosure agreements and other negotiations with to secure services from selected satellite-based change-detection and cell-phone data providers
- Select areas of interest for the proof of concept with help from a participating project sponsor and use those areas to help solidify costs versus the project budget, and
- Based on the timeline of data received and the project team's data analysis period, provide preliminary findings to the participating project sponsor.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

GNSS Testing in an Urban Environment

This project involves an investigation into current technology enhancements that can help field data collectors in difficult urban environments and best practices for their implementation.

Project Description

Data integrity, quality, and accuracy are crucial for gas utility operations, especially in highly congested urban areas.

Location-driven solutions often require a high-accuracy GPS signal to be adequate to alert contractors of a gas main encroaching in the area of their dig. Some utilities require total stations and other equipment to be used by licensed land surveyors in an urban environment, which can be time-consuming and expensive.

Global Navigation Satellite Systems (GNSS) continuously transmit navigation signals; however, the signals are very weak, can be blocked by any physical object on earth, can be interfered by electromagnetic fields, or can be reflected by different surfaces, such as tall buildings. In addition, GNSS receivers used for data collection need good sky geometry to compute an accurate position. When being in an urban canyon environment, such as a large city, many satellite signals are being entirely blocked by tall buildings. Other signals are being reflected by the building facades, which causes a timing delay and miscalculation of the range to the satellite.

This project involves an investigation into current technology enhancements that can help field data collectors in difficult urban environments and best practices for their implementation.

Deliverables

Based on the results in this study and lessons learned, researchers will provide recommendations for technologies and best practices of their use. A Final Report and webinar will be presented.

Benefits

GNSS technology is the most convenient way to measure the geospatial position of the gas system's assets and related activities. Today, high-accuracy GNSS data collection is an essential part of utilities' geospatial data management.

Finding ways to improve the accuracy and performance in the urban environment will benefit utility operations, increase efficiency, and improve the reliability of their digital assets.

Benefits

Developing the capabilities to leverage more accurate and modern data sources can help:

- Reduce labor hours categorizing new development
- Automate and produce more accurate population estimates
- Add population movement patterns to reinforce or reduce impact areas, and
- Improve emergency-response capabilities through pattern analysis of populations.

Technical Concept & Approach

This project's scope includes an evaluation of the potential of updating the methodology used to create potential impact areas as defined by PHMSA. Through new data sources and data-analysis capabilities, it is possible to update and track changes within human populations and urban landscapes that affect the delineation of consequence areas.

Specific tasks include:

- **Research Cell-Phone and Satellite-Data Options**

  This task will identify and obtain cell-phone data and satellite data. Aspects will include the ability to access data for a given time period, obtain data at a sufficient level of granularity, and review the accuracy of data collected by providers.

- **Identify Data for HCA\MCA**

  This task includes the identification of HCAs and MCAs as defined by the PHMSA guidelines. Sponsor feedback will be collected to find an appropriate area to conduct the comparison and data-collection activities.

- **Data Calculations and Comparison**

  This task will calculate and compare data obtained for the same geographic areas and define a potential impact radius polygon. A time-series analysis will be conducted to determine the extent of change in population and urban development that has occurred.

This analysis will be conducted using GIS software and will result in an animated graphic depicting the results from year to year, including comparison of the results from using different data sets for the analysis.

Results

This project was initiated in 2021 with a review of the HCA and MCA regulations from the PHMSA. Researchers created a list of vendor companies that provide cell-phone and imagery-based change detection services. The project team also identified potential project sponsors for subject-matter expertise discussions.

Project representatives contacted multiple vendors and received multiple demonstrations regarding their products. Additional meetings were conducted to retrieve sample data or examples of results based on a fictitious dataset. The project team utilized this sample dataset to help establish a workflow with the vendors as well as pricing. A project sponsor provided additional information on its HCA and structure-verification processes.

The research team received initial cost estimates from both satellite-based change-detection and cell-phone data providers to use in conjunction with the project's budget. Separate data was acquired sample data from three separate cell-phone providers and reviewed for potential use in the project's proof of concept.

Sample images and a web map example were received from two satellite-based change-detection companies.

Researchers began the initial stages of communication with an internal legal team regarding the proper path to secure services from selected satellite-based change-detection and cell-phone data providers.

Status

The following activities are scheduled for execution:

- Complete non-disclosure agreements and other negotiations with to secure services from selected satellite-based change-detection and cell-phone data providers
- Select areas of interest for the proof of concept with help from a participating project sponsor and use those areas to help solidify costs versus the project budget, and
- Based on the timeline of data received and the project team's data analysis period, provide preliminary findings to the participating project sponsor.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

RISK & DECISION ANALYSIS MODELS

In this area, researchers are developing models, methodologies, implementation protocols, and case studies that will allow natural gas system operators to more effectively manage operations data and improve the decision-making process.

Programs in this area employ a multi-disciplinary process that includes risk assessment, characterization, communication and management, and related research for decisions optimization. The output of the program includes predictive models, calculators, and databases that describe the complex and interconnected behavior of utility infrastructure systems and their risks.

Initiatives include the development of a data collection, normalization, and integration methods to enhance risk-assessment tools for decision making.

.

Data Collection, Normalization, and Integration Methods to Enhance Risk Assessment Tools for Decision Making

In this project, researchers applied machine-learning, causal-modeling, Bayesian networks, and decision-science methods to the challenge of data normalization, data analytics, and data synthesis. Efforts were made to ensure that the methods support decision-making processes and situational awareness in the context of the natural gas infrastructure.

Project Description

In this project, researchers explored the application of various kinds of statistical and machine-learning techniques to identify the quality, reliability, and traceability of sensor data in assessing integrity risks.

The project team:

- Developed improved methods for estimating risk levels within a pipeline risk-management system
- Developed methods to estimate the value of information provided by sensors of various types in different applications, and
- Developed decision tools to support pipeline-integrity managers in selecting the most cost-effective additions to sensor networks in terms of reduction in expected risk within a given budget for risk management.

A project team evaluated a selection of the most widely used and most promising new sensor types applied to a variety of types of transmission, distribution, and other gas facilities. The team applied multiple machine-learning, causal-modeling, and Bayesian network techniques to the challenges of normalizing, integrating, and analyzing disparate data streams. The focus was on identifying the issues, enhancements, and extensions needed, and to design and develop prototypes.

This project was co-funded by the U.S. Department of Transportation's Pipeline and Hazardous Materials Safety Administration.

Deliverables

Within this project, the main deliverable is the development of a decision-support tool. The tool incorporates new methods and models for risk estimation developed by the project team and makes them accessible and useful to risk managers at gas utilities.

Benefits

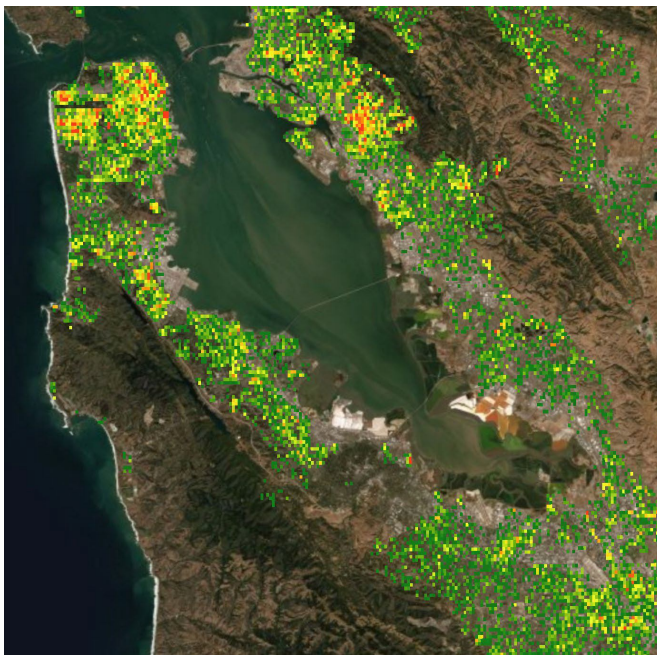
An improved decision-support tool will help to lower the costs of risk management and improve overall system safety and integrity.

Technical Concept & Approach

In 2020, a primary task was to conduct a survey of risk managers at gas utilities to identify their current practices and priorities for improvements. The project team followed up with selected respondents and some new respondents to develop deeper insights.

The approach to discovering how gas utilities assess and manage infrastructure risks has three phases:

1. **Initial meetings:** Researchers arranged in-person and web-conference meetings with senior risk executives and their teams at selected gas utilities. In these meetings, the project team asked for an overview of current approaches used to assess and



Example of an annual trace gas analysis.

"The Bayesian Network research will allow us to derive new insights by connecting a broad number of pipeline and external attributes in mathematically meaningful ways to better understand how they interact and ultimately result in leaks and third-party damage."

- Aaron Rezendez
Engineer, R&D and Innovation
Pacific Gas and Electric Company

manage risks, to obtain key documents that describe their current practices, and to nominate staff to respond to an online survey. Utilities on the Technical Advisory Group were also asked for access to data used for risk assessment (including data on assets, threats, incidents, and responses) for use in developing new types of analysis and tools for the research project.

2. **Online survey:** Researchers provided an online survey to obtain more detailed information in a standardized form on current practices and priori ties for one or two respondents at selected utilities.

3. **Post-survey interviews:** The final survey question asked respondents if they are willing to provide a 30-minute follow-up telephone conversation to give them the opportunity to clarify their answers and give more specifics if they wish.

Results

Several themes emerged from the initial survey responses. Respondents also identified challenges for their organizations and opportunities they would most like to see addressed.

In 2020, the project team and its primary contractor designed and developed a decision-support tool that incorporates the methods and models for risk estimation developed by the project team and be made accessible to risk managers at gas utilities. The tool is designed to collect, normalize, and integrate risks from models; assist in decisions on risk-mitigation projects; and develop initial mock-ups of user-interface screens.

In 2021, dded to the tool were:

- A lifetime prediction module
- Inference tools for identifying asset characteristics correlated to predicted lifetimes, and
- A flexible and user-friendly regression module to empirically identify asset and regional characteristics influencing asset leakage.

A refined Bayesian network model was developed and implemented in a software platform. Researchers demonstrated that the model accurately captures nominal system performance and appropriate design factors. The current model provides a powerful reasoning framework that can be used to both predict system performance given known inputs, and reason backwards to suggest potential root causes of observed situations.

A team at Stanford University team was tasked with producing data-driven insights into natural gas distribution system integrity management via machine learning, data discovery, econometrics, or causal inference, with a working model at scale. The Stanford team focused on assessing the relationship between ground movement and distribution leaks using a variety of data sources. All attempts to gain insight into this relationship on a purely statistical or data science basis have produced at best null results (i.e., we found clear evidence that one cannot meaningfully predict leak incidence based on satellite-measured ground movement data, at least on timescales of a few years).

If utilities were able to collect such data at low cost in a way that accurately reflected the state of the full asset base, such models could allow distribution utility integrity management teams to more accurately predict the evolution of local system integrity, allowing more efficient prioritization of preventative maintenance and replacement resources.

Many of the key parameters, such as the precise plastic composition, rough material quality, and local soil composition can be extracted, at least in part, from photographs of the excavated assets. Such a photographic dataset could be combined with computer vision algorithms to automatically learn local asset and soil characteristics necessary to calibrate a causal physical model well enough to produce decision-relevant insights. This approach could provide utility integrity management teams with low-cost tools to help improve system-wide safety and environmental performance.

Status

This project is completed. A Final Report is being developed.

For more information:

Michael Adamo, P.E.
Vice President, Operations
Operations Technology Development, NFP
Phone: 847/544-3428
michael.adamo@otd-co.org

Operations Technology Development, NFP

1700 S Mount Prospect Rd
Des Plaines, IL 60018

Info@OTD-co.org
847-544-3400

www.otd-co.org