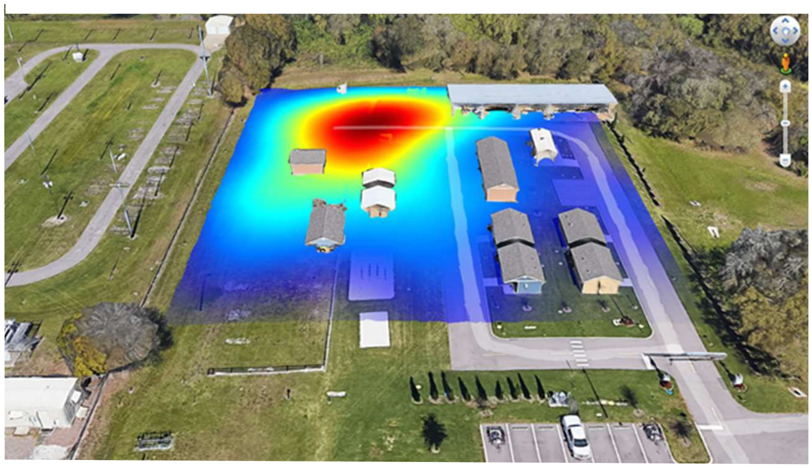
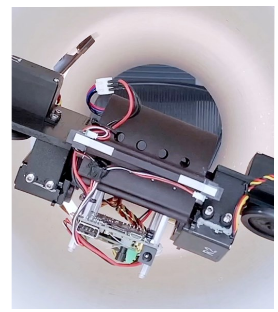
OTD

Operations
Technology
Development

RESEARCH PROJECT SUMMARIES
2022-2023







Operations Technology Development, NFP

RESEARCH PROJECT SUMMARIES

2022-2023

Legal Notice

Chairman / President's Letter

The gas pipeline and storage network 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 29 member companies who serve over 60 million customers in the U.S., Canada, and France.

OTD's work plays a critical role in driving innovation and research to facilitate and aide in the energy transition. By leveraging the vast pipeline infrastructure, OTD members are uniquely positioned to deliver energy solutions that are safe, clean, reliable, and affordable. As new challenges emerge, OTD works to identify solutions that enhance public and pipeline safety. Our members remain committed to integrating new technologies, processes, solutions and information to the benefit of ratepayers and society.

OTD also partners with key stakeholders such as the Department of Transportation Pipeline and Hazardous Materials Safety Administration (DOT PHMSA), the Department of Energy (DOE), state agencies, and technology developers to identify solutions to critical priorities. These partnerships grow increasingly important as the industry seeks to meet environmental goals, and do so without compromising public safety, pipeline safety, and system resiliency.

This report provides summaries of more than 100 projects spanning 2022 and 2023 within OTD's program and includes an overview of several of OTD's most significant achievements. 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 relies 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. Continuing to leverage this expertise and working hand in hand with technology leaders helps us continue to drive innovation and solutions that meet rapidly evolving energy goals.

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
> Blackhills Energy
> 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 Utilty
> Southwest Gas Corporation
> Spire (Alabama)
> TECO Peoples Gas
> Washington Gas

Chair of the Board

Michelle George

President

Ron Snedic

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

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, facilitating 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: Tim Beed
803-222-8400
tbeed@spartacoGroup.com
www.jamesonllc.com

Kleiss MCS Flow Stopping System

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

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 re- porting and monitoring. LocusSurvey eliminates paper maps and records, automating the process of documenting surveys and leak locations.

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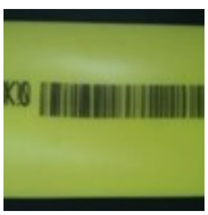
www.locusview.com

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
rpurczyn-
ski@integratedtoolsolutions.com
www.integratedtoolsolutions.com

HaloValve Breakaway Device

OPW Engineering Systems

When a natural gas line is broken or breached at the meter set assembly, an uncontrolled natural gas leak occurs. Upon a hard impact, the HaloValve breakaway immediately seals until the line can be repaired.

Contact: David Jacobson
1- (513) 816-2769
david.Jacobson@opwglobal.com
www.halovalve.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: Ryan McGowan
631-667-9200
ryan.mcgowan@spx.com
https://ulctechnologies.com

Live Gas Mapping

Reduct

The ability to enter live gas pipes eliminates downtime during the mapping procedure, meaning there is no disruption in service to your customers. This probe can map buried live gas transmission and distribution pipelines.

Contact: Otto Ballinjin
Otto.Ballintijn@reduct.net
https://reduct.net/

Hathorn Inspection Gas Camera

Hathorn

The system was designed to as a way for utilities to inspect live gas mains through 90-degree keyhole pipe entries. The Hathorn Inspection Camera can inspect 2-6” gas mains while recording inspections to USB or HDD.

Contact: Rob Luck
1-905-604-7040
rob@hathorncorp.com
www.hathorncorp.com

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.

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.

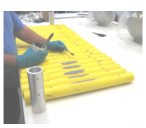
Cross Bores Best Practices Guide & Video

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

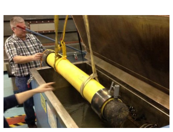


Repair Wrap for Polyethylene (PE) Systems

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

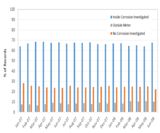
This report details the results of testing conducted to evaluate the long-term performance of liners and composites used in trenchless operations for the rehabilitation of aging gas distribution and transmission lines.

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).

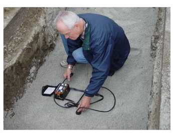
EXCAVATION & SITE RESTORATION

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.

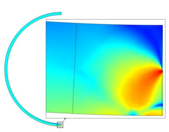


Evaluation of Flowable Fill Around Buried Pipes

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

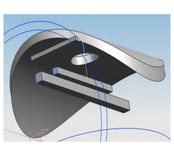


Correlating Pipeline Operations to Potential Crack Initiation, Growth, and Arrest

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.

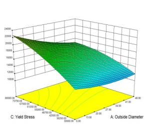
Hydro-Testing Alternative Program

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).



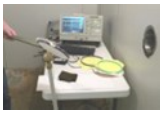
Leak-Rupture Boundary Report and Calculator

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.

PIPELINE INTEGRITY MANAGEMENT & AUTOMATION



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

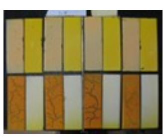
Extensive research and testing culminated in the release of a report that provides valuable information on the properties and performance of various tracer-wire products for use in horizontal directional drilling (HDD) operations. (OTD-13/0001)

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.

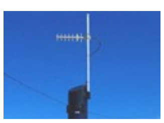
Assessment of Vehicle-Barrier Design for Aboveground Facility Protection

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.

Tracking and Traceability Standards

ASTM F2897 "Standard Specification for Tracking and Traceability Encoding System of Natural Gas Distribution Components (Pipe, Tubing, Fittings, Valves, and Appurtenances)" was developed in part by OTD, and adopt the worlds most used product identification standard GS1.

Data Collection, Normalization and Integration Methods to Enhance Risk Assessment Tools for Decision Making

Co-Funded by PHMSA, this project looked to create methods and software tools to help operators of natural gas pipelines better estimate risks and improve risk-mitigation decisions

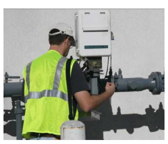
Pull Load Calculator

The WEAKLINKapp allows trenchless contractors and field personnel to select an appropriate weak link so that trenchless installed HDPE and MDPE gas pipes are not overstressed during their installation. It also allows field personnel to determine if the weak link being used on a job, is in accordance with the GTI Horizontal Directional Drilling Weak Links report, federal regulations, and weak link requirements.

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

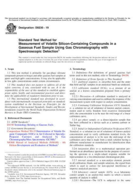
This report summarizes the results of field surveys conducted at six natural gas utilities. With the support of the American Gas Association, research updated emissions factors for metering stations, regulating stations, and customer meters. (OTD-10/0002)

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.



Standard for Siloxane Content in Biomethane

The purpose of this project was to develop, in conjunction with ASTM Committee D03 on Gaseous Fuels, an industry-wide sampling and analysis standard for measuring siloxanes in biomethane that could obtain a detection limit of 0.01 mg/M3 of silicon or less. Work resulted in a new ASTM standard test method D8230-19 “Standard Test Method for Measurement of Volatile Silicon-Containing Compounds in a Gaseous Fuel Sample Using Gas Chromatography with Spectroscopic Detection“ to be created and published in 2019.

OTD RESEARCH PROJECT SUMMARIES
2022-2023

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INTELLIGENT UTILITIES

Project **Page**

INTELLIGENT UTILITIES (Cont.)

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.

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Project No. 2.10.b

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. The can also 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.

In Phase 1 of this project, a comprehensive evaluation of polyurea pipe coatings was conducted to determine: cathodic disbondment, impact resistance, abrasion resistance, UV resistance, and corrosion resistance.

Two types of polyurea coatings performed well in laboratory testing. 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/Status

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.

This project continues to be a long-term inspection of the coating of an in-service pipe by the utility. All tasks and activities are complete and the final report was delivered in May 2023.

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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.

Project No. 4.17.a

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

Deliverables for this project include a prioritized list of DA applications from an operator's perspective; a report identifying 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**

Congested meter regulator station DA site with crossing situations.

This

task includes determining the system configurations where use of DA is most critical and where 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-assess-ment 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 report also includes responses to a sponsor survey and information on ECDA strengths and weaknesses.

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

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

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.

During 2022, the project team met to review the project scope and roadmap to assess its relevancy given the industry developments that have transpired since the project's inception in 2018.

Status

In the years during and since initiation of the PHMSA "Mega Rule," the regulatory and industry perspective has shifted towards viewing Direct Assessment as a supporting methodology until operators are able to conduct a more robust method such as Hydrotesting, In-line Inspection (ILI), a new technology or approach, or an Engineering Critical Assessment (ECA). Nonetheless, many of the 48 enhancement opportunities identified in this project may be equally applied to these other pipeline inspection methodologies. An interim Final Report was issued in March 2024 that summarizes activities and results that occurred related to the original project objectives. In light of the federal regulatory changes underway, the remaining tasks for this project are being evaluated to see if a change in focus is warranted.

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OTD
Operations
Technology
Development

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:

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.

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.

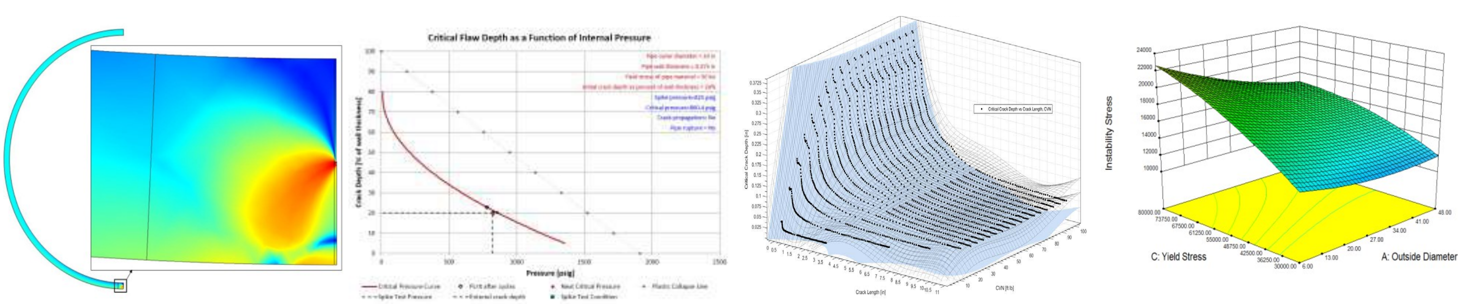
4.9.a Leak-Rupture Boundary Determination

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.

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. This will include a surface-chemistry-based model to predict yield ultimate tensile strength with an established confidence, a database of through-wall properties by steel type/vintage for typical pipelines, and probability distributions of the difference between surface and bulk chemical properties.

In addition to these four bodies of work, the project team will leverage the adaptive sampling and



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

conditional probability analysis developed as part of the OTD Yield Strength Determination program and various other sampling projects.

Deliverables

The deliverable for 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.

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/Status

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 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 software application approach for an ECA tools framework. The application enables the generation of wall loss values based on user inputs for pipe diameter, wall thickness, minimum yield strength, operating pressure, and safety factor.

During 2022, a leak rupture boundary calculator and related plot functionality was created that enable values to be generated based on inputs for items such as crack length, yield strength, diameter, and thickness. The Consolidated ECA Toolbox Application was finalized and demonstrated to project sponsors.

The Final Report User’s Manual describing the Consolidated ECA Toolbox Application was delivered in January 2023.

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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.

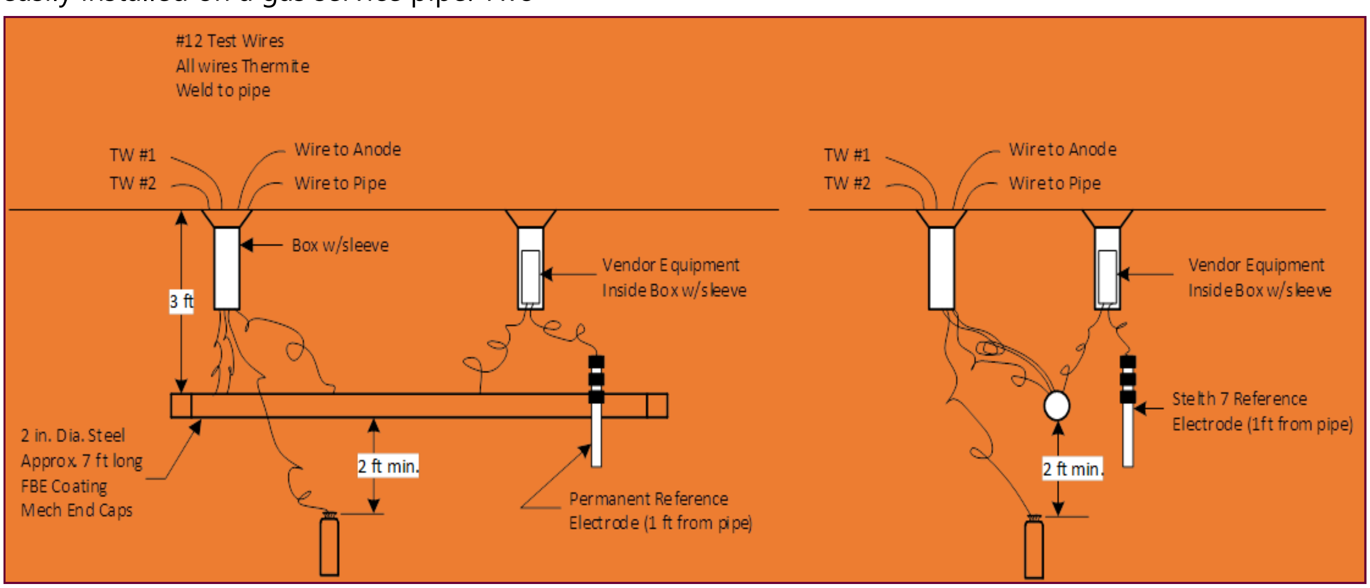
Deliverables

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 GTI Energy pipe field in Des Plaines, IL.

Both vendor's monitoring units demonstrated ability to perform internal pipe-to-soil measurements and transmit measurements to a web-based data collection system. Physical measurements were agreeable with remote measurements with only two physical and technical issues occurring. Water infiltration only occurred in one unit (of six) and was easily replaced with no continued failure. Signal loss occurred only once with a single device, data was backed up locally and recovered. Issues such as these were readily seen through uploaded system data, allowing for immediate inspection and quick repairs. Data can also be recovered in the event of network issues and all data could be exported to local files at customer's discretion. All data was transmitted through cellular connections. Continued work will be needed to move both networks onto secure lines such as Silversprings and LoRaWAN. Within the equipment this will require network modules and battery upgrades to assure continued efficiency. These updates will be pursued in a Phase 2 effort.

Status

The Final Report was delivered in August 2022.

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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 micro-encapsulation 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, the surface preparation and cost are disadvantageous to operators.

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

Deliverables

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 reduce maintenance costs.

Technical Concept & Approach

Specific tasks for this project 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/Status

This project conducted product development, coating application, and laboratory testing of self-healing coatings from Autonomic Materials (commercialized by Rust-Oleum) and Hexigone

Inhibitors. The current success of self-healing

coatings has been demonstrated in a liquid, two-part epoxy coating primer, which is mostly used by utilities on aboveground utility assets. Project Sponsor Surveys focused the use cases on soil-to-air interfaces (risers, meter sets), difficult geometries (unions), and water-to-air interfaces (bridge crossings, vaults).

The most notable improvement in performance from the AX1 additive is in pull-off adhesion and rust creepage. Between the Hempadur 45880 without AX1 and Hempadur 45880 with AX1, pull-off adhesion more than doubled, and rust creepage reduced by 20% in the same base primer.

The Rust-Oleum META Prime primer showed 70% of the pull-off adhesion of the Scotchkote 323+ benchmark but with six times less thickness. In addition, the integrity of the coating was not compromised due to the additive, as seen in the similar results for the UV condensation tests, cure, and corrosion profiles. Creep mitigation of META Prime is similar to the industry benchmark, but VOC (Volatile Organic Compounds) emissions (340 g/L) are high.

After discussing the results with the manufacturer of AX1 (Hexigone Inhibitors) and the manufacturer of AMP-UP 100 (a newly introduced self-healing additive from Autonomic Materials), both provided GTI Energy with additional testing data. Hexigone Inhibitors repeated the pull-off adhesion test with greater improvements when comparing coatings after 2000 hours of salt fog exposure.

This project's findings support further laboratory testing of Autonomic Material’s AMP-UP 100 to confirm their recent studies that concluded better rust creep resistance and pull-off adhesion compared to the industry benchmark.

This project is complete and a final report has been shared with OTD members.

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CONSTRUCTION/ INFRASTRUCTURE

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.

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Cybersecurity Working Group

This project will establish and facilitate a focused working group in order to develop a comprehensive strategy to effectively mitigate cyber threats aimed at energy industry critical infrastructure.

Project Description

The goal of this project is to establish and facilitate a focused working group intent on building a strategy to help operators mitigate cyber threats aimed at energy industry critical infrastructure. Through execution of an initial workshop, the team will identify needs and develop a research roadmap that outlines the elements needed to protect against the disruption and destruction of natural gas infrastructure.

Deliverables

Deliverables for this project will include a final report documenting the findings from the workshop, a strategy to mitigate natural gas infrastructure cyber-attacks, and a cybersecurity "library" site.

Benefits

In order to help mitigate the risk of cyber-attacks, solutions are needed to address the varied equipment that may be impacted from potential cyber attacks. Potential mitigation must be considered ranging from industrial control systems, embedded systems, and bulk power equipment to smaller footprint, remotely deployed Operational Technology (OT) like sensors, communications hardware, and other Internet of Things (IoT) devices.

This project aims to identify potential integrated solutions providing real-time situational awareness of the natural gas operating environments.

Technical Concept & Approach

Cybersecurity Workshop

Host a workshop with utilities on cybersecurity which establishes a baseline of technical information, describe the security solution landscape present-state, and identify where additional research may be required.

Cybersecurity Roadmap and Content Repository

This looks at developing a strategy for helping mitigate cyber-threats based on workshop results and feedback from operators. Priorities for addressing natural gas infrastructure cybersecurity may fall into a variety of strategic initiative categories such as focused research projects, industry needs and education advocacy, consulting, and technical support for operators and regulators. This will take into consideration the large number of stakeholders who play a role in mitigating cyber-attacks and the unique and innovative ways they will need to be engaged. Upgrading the present web-based cybersecurity repository to house information on new studies, projects, reports, conference proceedings, and more that will be made available to members.

Results/Status

In 2023, the working group met to describe natural gas critical infrastructure security landscape trends, review traditional IT monitoring systems shortcomings, and discuss the desired situational awareness future state. Focus areas for organizing research priorities were defined, discussed, and agreed upon. The identification and build out of the initial version of the research priorities occurred. A prioritized roadmap of research items is expected during Q3 of 2024.

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OTD
Operations
Technology
Development

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.

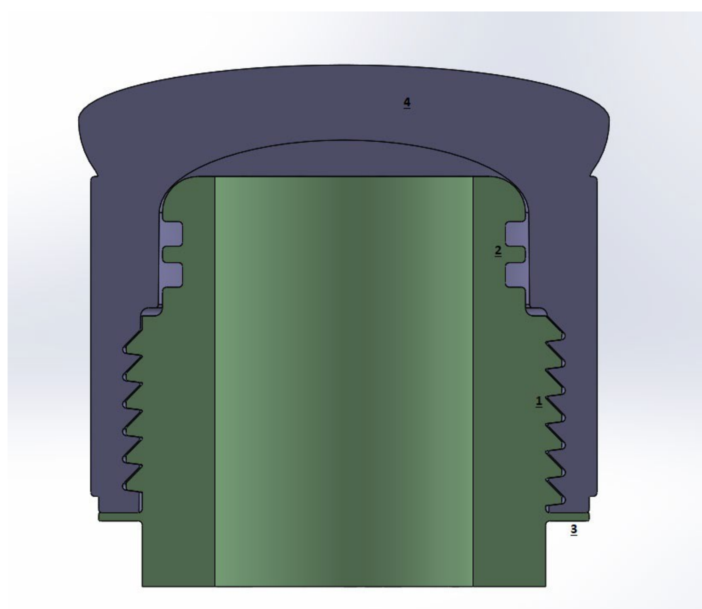
Benefits

Working to reduce PE service-tee nuisance leaks allows gas utilities minimize excavations for repair and provide cost savings.

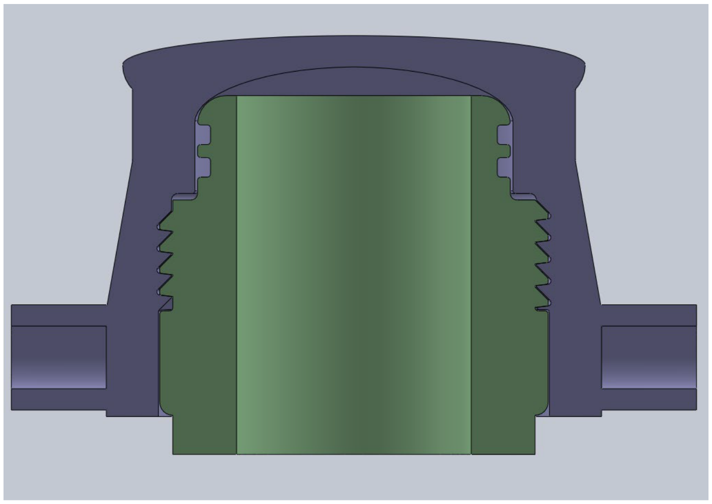
Service-tees can leak if caps are accidentally cross-threaded or over-tightened during installation, or have an O-ring installed in the wrong position. They can result in the cap losing its leak-tight seal.

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.

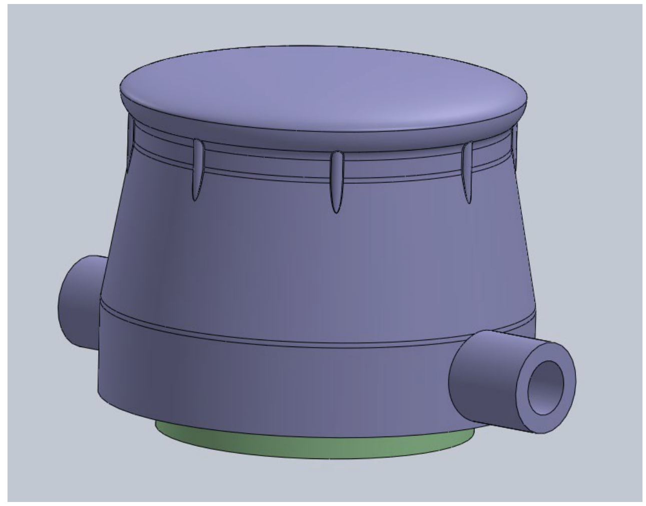
Assembled service tees



Cross section view of the PE cap assembly (2")



Electrofusion cap concept, cross-section



Electrofusion cap concept, external view

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/Status

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

The team worked with Georg Fischer Central Plastics (GFCP) to review and design an alternative cap. The developmental work performed by GFCP on the heat fusion cap is promising, however, the process that they have created only works with fittings that are designed for this purpose which is not interchangeable with existing product or fittings from other manufacturers.

GFCP looked at several different concepts for building the electrofusion (EF) cap. After evaluating all of the concepts, the most universal concept would be to build an EF 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 GFCP to offer both a standard and an electrofusion cap for their service tee product line. No changes to the standard product would be required. This proof of concept still needs to be built and tested, and potential challenges related to liability for using alternative caps needs to be evaluated.

The project team will complete and issue a survey to the Sponsors to identify and document the Sponsors' requirements for an alternative cap/fitting.

Phase 1 of this project is complete and Phase 2 has been approved. Phase 2 aims to design an alternative cap for polyethylene service tees to mitigate the risk of nuisance leaks caused by cross-threading, overtightening, and improper O-ring installation. A fused cap design, which directly bonds to the tee body or tower, presents a promising solution to minimize these nuisance leaks, enhancing the reliability and longevity of the service tees.

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ORFEUS Obstacle Detection 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 to bring forward a commercially viable product for identifying obstacles in and around the path of a HDD drill rig.

The project goal 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. Field evaluations will be continued with ORFEUS to demonstrate continual successful operations.

Deliverables

The deliverables for this project include field demonstrations, reporting on the enhancements incorporated into the ORFEUS system and 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.

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.

Technical Concept & Approach

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

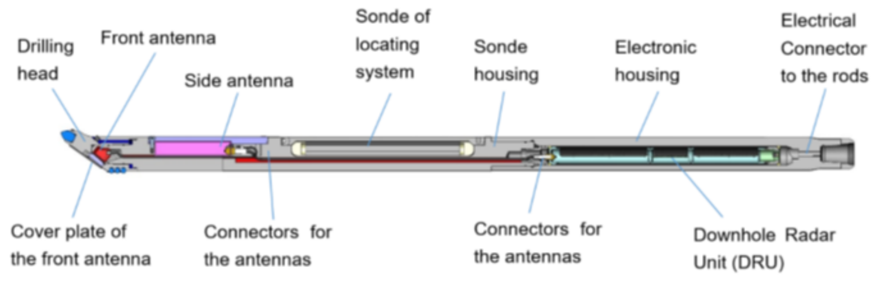
Improve and production-engineer the modem and power modules, both in the cab and at the drill head based upon the existing design and digital signal processor architecture enhanced by using information gained from the previous project's field trials.

System Software

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.



Assembly of the downhole equipment.

Operational Tests

Operational demonstration trials to confirm the operational reliability and readiness of the system will take place.

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.

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

The small space available for hosting a front antenna constrains the height of the electronic boards for the microwave source and receiver. Thus, a whole re-design 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.

In 2023, the first operational systems trials were carried out in Lennestadt, Germany, at a test site. The completed hardware and software were installed on an HDD drill rig. The aim of the test was to test the integration of the entire system. Testing began of the complete system with the integrated front and side antenna. The technical team finished the development and debugging of the data acquisition module and completed the modifications of the ORFEUS detection algorithm and the angular sensor board. It is now possible to calculate the pitch angle and the angular speed in real time. The technical team continued to address various enhancements related to the radar and antenna system on the bore head, the communications link and coax connections in the rods, and radar software.

Status

The project team is continuing to make small modifications based on field trial results. Additional field trials are planned to be conducted in Germany. The team built a second ORFEUS drill rig which was shipped to the US for a field trial in the first half of 2024.

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

Research is under way in an 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 piping system.

In an 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.

From top to bottom: plastic pipe, bare steel pipe, bypass pipe, coated pipe, coated and welded pipe

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.

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 pickling 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, evaluated, and presented to project sponsors with recommendations to select processes for further study.

Selected techniques will be evaluated under laboratory conditions. Individual steel test pipes will be obtained so that low-pressure, low-flowing gas can be introduced and measured at various time intervals. The gas will initially be odorized with tetrahydothiophene and/or TBM, using house gas or synthetic odorized gas.

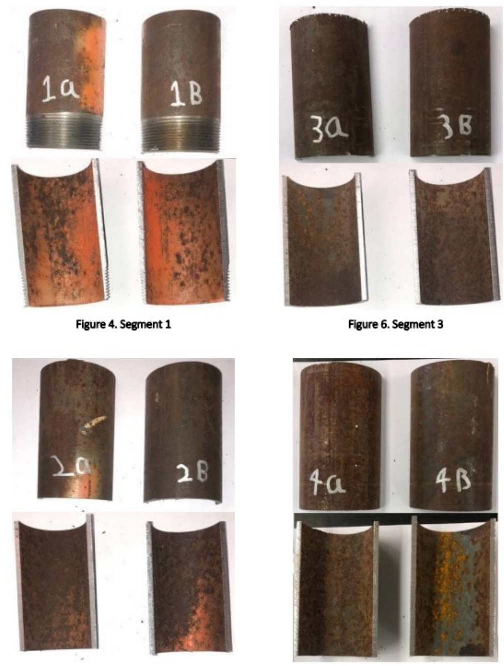
Results

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, 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 during project planning the impact of rust on time to saturation for uncoated steel pipe to calculate when odor fade may occur. As this represented an addition to the project scope, in the interim, the team produced an initial time to saturation analysis to outline the methodology a utility could use to develop a risk of odor fade "rule of thumb" estimate 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 included pictures, examination, and collection of loose surface rust. Sample pipe was cut into four-inch segments then 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 completed testing at residential infrastructure pressures and flows. A logistic model was applied to the data collected for purposes of determining a steady state breakdown rate. The final report was delivered in January 2023.

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OTD Operations Technology Development

Modify Pipeline Purging Program for Calculations of Methane Emissions Savings, Including Hydrogen Blends

The objective of this project is to update GTI Energy/B3PE LLC's pipeline purging software program GASPurge™, to allow users to calculate methane emissions savings more easily from using various types of purging alternative processes and equipment (i.e., cross compression) and through hydrogen blending.

Project Description

- OTD members are using equipment and procedures that repurpose natural gas that would have been normally vented to the atmosphere. Quantifying the emissions savings from using these types of equipment and improved procedures can be difficult. As operators implement hydrogen blending, quantifying emissions savings from hydrogen will also be an important part of emissions reporting.
- This project will update the current GASPurgeTM software program to enable users to quantify methane emissions consistently and accurately. The project team will collaborate with manufacturers to enhance the purging software to calculate the emissions savings when using the methane savings-equipment. The intent is to support operators in determining the optimal strategy for emissions savings by considering various factors:
- Gas composition (e.g., if there is blended/free hydrogen in the gas supply)
- Equipment type (e.g., types of compressors used, fuel source used for the equipment)
- Transportation distance (e.g., emissions associated with equipment delivery)
- Emissions savings methods for both methane and carbon (e.g., cross compression, flaring)
- Feasibility breakeven analysis for emissions footprint (e.g., is the use of equipment providing a positive environmental footprint?)

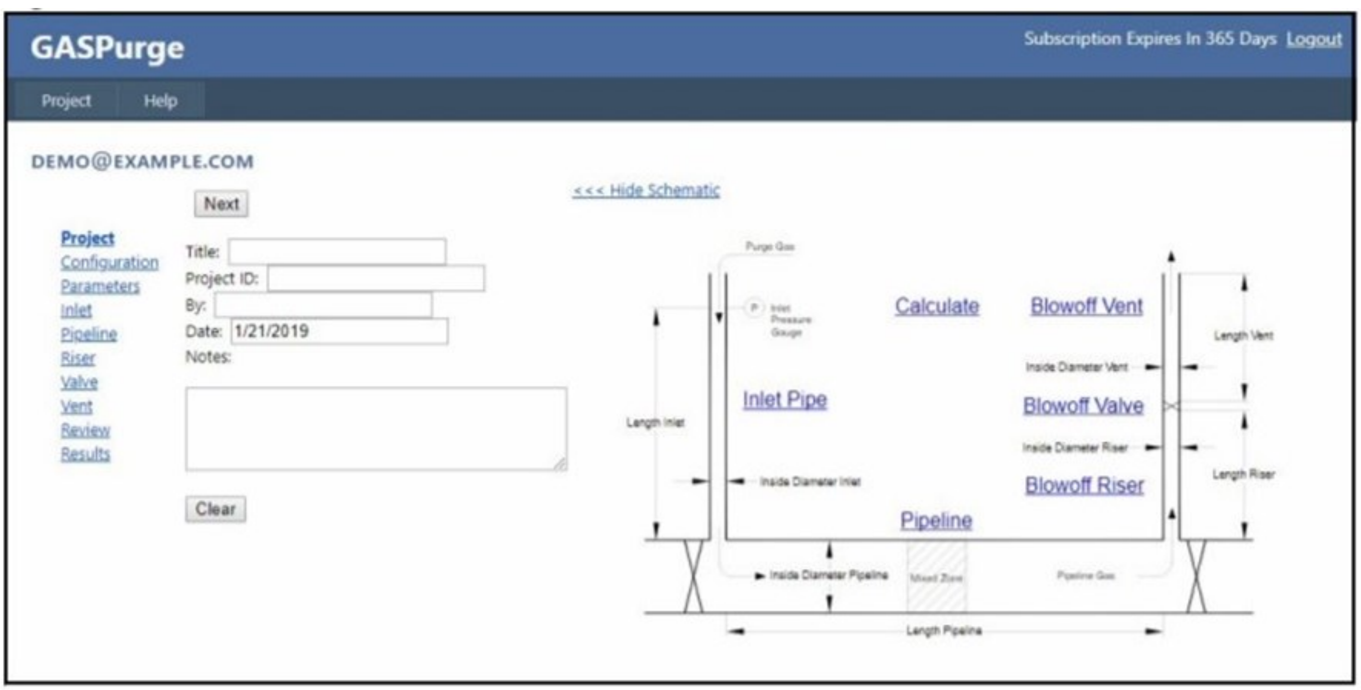

Figure 1: Current GASPurge^{TM} interface that will be updated with this project.

Deliverables

- Distribute beta version of software to project sponsors for input and feedback and facilitate live demonstration.
- Complete and distribute the production version of the software at the conclusion of the project.
- Quarterly, final reports, and review meetings as necessary.

Benefits

This project will support operators with the calculations for emissions savings reporting to state and federal governments or corporate environmental, social, and governance (ESG) and assist operators in choosing the best method for avoiding venting and minimizing the overall environmental impact of their operations.

Technical Concept & Approach

The software's algorithms will meet the US Environmental Protection Agency's (EPA) Greenhouse Gas Reporting Program (GHGRP) requirements. This means that the software will consider the global warming potential (GWP) of the mitigated emissions and offer reporting on a carbon equivalent basis. Similarly, the software will account for emissions due to flaring, diesel combustion from compressors, and emissions from the transportation of equipment. All these emissions will be quantified separately in the software and their GWP will also be reported. Accounting for all these emissions will assist operators in choosing the best method for avoiding venting and minimizing the overall environmental impact of their operations.

Results

The project kick-off meeting was held in August 2023, a project survey was sent out to sponsors to understand the type of equipment, methods, and processes sponsors currently utilize for purging operations and if alternatives would be considered for future operations. This knowledge will be used for developing the updated purging program.

Status

The project team is currently developing the software update, and proposed methods for calculating emissions for updating the GASPurgeTM software program was shared with project sponsors. The team is seeking input from sponsors to ensure that the existing software updates align with methods that are currently being used. The project is on track to be completed by December 2024.

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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. These coatings have the potential to reduce wet/dry aboveground corrosion in various areas of application.

Project Description

Corrosion is a never-ending threat to utility asset integrity. Long-lasting coating protection will reduce the amount of rework needed for operators on their aboveground systems.

In this project the team investigated unique and promising coatings for challenging aboveground utility corrosion prevention applications. These coatings have the potential to substantially reduce wet/dry above ground corrosion in areas of highway crossings with caustic bird droppings that lead to steel leafing corrosion and significant coating breakdown, bridge, river, and waterway crossings with high moisture and potential road salt contamination, ice and snow areas that cause meter damage (i.e., snow and ice cannot stick to hydrophobic nano-coating) as well as premature coating failures, vaults with high relative humidity, wet-dry cycles, and infrequent inspection access, meter and regulator stations, including "sweating" pipe locations downstream of regulators, and areas of heavy road salt or fertilization.

Deliverables

Specific deliverables from this project include a set of applicable use cases in a gas utility for these coating systems, field test results, a coating-performance summary, recommendations for specific uses of the product, and a Final Report detailing all activities.

Benefits

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.

Field testing these unique coatings in the natural gas utility environment provides 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.

Bridge Crossing Applications


As received dummy pipe


Before and After Blast Comparison


Coated Pipe

Technical Concept & Approach

Tasks for this project include use case and field site selection, product review and selection, development of a field-testing protocol and testing matrix, and field trials and performance assessment.

Results/Status

The team worked with the sponsor group, OTD as a whole, and consulted with the AGA Corrosion Ad hoc Committee to establish a use case list for potential use of these products. Three viable and very high-performance coatings systems from non-gas utility sectors were selected. Working with sponsor companies, the project team planned and arranged and executed the field trials. Field exposure was approximately three years.

All three of the coating systems performed well. Each coating system has particular strengths based on the system's formulation and base resins and additives. The coatings were tested in four distinct environments including a regulator station, bridge crossing, coastal location, and desert location.

Testing was done on scribed and not-scribed samples for the dummy pipe sections. The regulator station testing included live (gas flowing inside) pipe.

The harder coatings appeared to provide significant adhesion of their hard and well-formed coating layers, with galvanic protection to the scribed areas, and the softer coating appeared to somewhat self-heal upon the scribing operation, and its hydrophobic and moisture displacing properties along with its alkaline pH nature possibly neutralized active corrosion cells.

There were a very limited number of mechanical damage from handling or blistering due to surface preparation or application issues, but these were localized and not reported since they were not due to the coating systems themselves. The mechanical damage was only seen in the softer coating, which is softer by design to allow it to overcoat existing coatings without residual stresses that can cause failure of the underlying base coating.

All three coating systems performed well in the extremes of desert heat and nighttime cold with morning condensation.

The harder coatings were used on the bridge crossing and also performed well under the winter, road salt, and bird dropping conditions. The softer coating was also used as an overcoat and appeared well intact except for the mentioned mechanical damage sections.

For the regulator stations all the coatings performed well both on live pipe and dummy pipe with and without scribes. Some of the coatings were discolored a bit, likely due to intermittent wet and dry cycles coupled with particulates in the atmosphere. However, this resulted in no degradation or corrosion.

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Leak Seal for Meter-Set Joints

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

Project Description

Through conducting leak surveys and leak investigations on residential and commercial meter set assemblies (MSAs), many utilities have found non-hazardous (i.e. low leak rate) leaks occur at threaded joints between components. Currently, a common practice to repair leaks on an MSA is to dismantle/ disassemble the MSA, replace a majority of the pipe and fittings, and reassemble the MSA. This requires customer downtime, relighting and inspection of customer appliances, and time involved in conducting the repair. Additionally, many of the MSA components (other than the leaking thread fitting area) are in good working condition and do not require actual replacement.

Typically, when assembling a MSA utility crews use pipe “dope” (joint sealant) on pipe thread as a 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 an effective seal. But over time the bond can become rigid and brittle in nature. Aging and temperature cycling can cause these brittle sealants to crack, creating small leak paths around the pipe threads. As the cycling continues, dry crack propagation continues and impacts the leak rate.

In this project, researchers are investigating alternate solutions involving the application of external leak sealing material to leaking threaded joints to stop gas leaks. Researchers identified various spray-on, brush-on, putty, epoxy, and tape-wrap solutions.

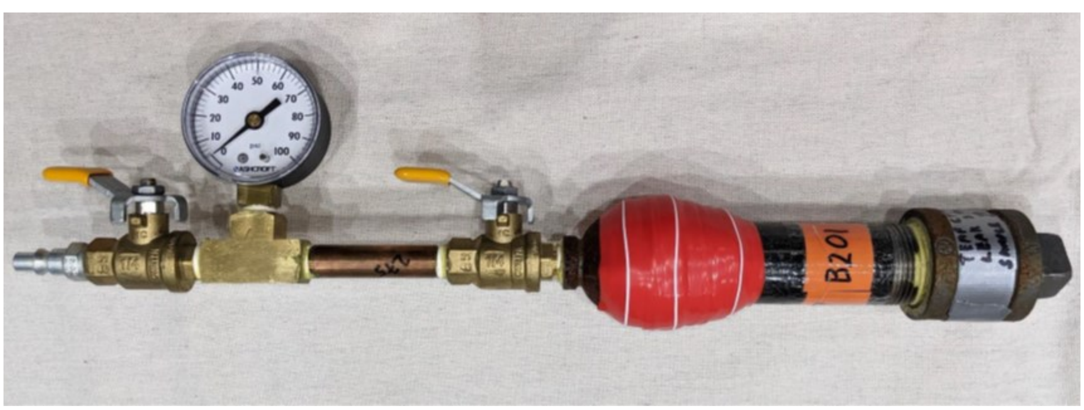
The objective of this project is to identify effective and efficient leak sealant repair solutions for non-hazardous gas leaks on MSAs to reduce or eliminate the disassembly/repair/reassembly of MSAs.

Deliverables

The deliverables from this project include a final report that identifies effective and easy-to-apply leak sealant products that have been laboratory tested specifically for the natural gas industry.

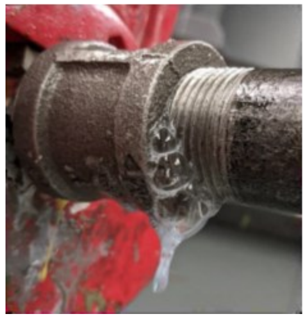
Benefits

Utilities could more effectively and efficiently address non-hazardous leaks on MSAs if an easy-to-apply system was identified, tested, and validated for use on natural gas leaks. Addressing these small non-hazardous “nuisance” leaks on 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.



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

Other tasks included:

- Resin Manufacturer Collaboration and Reformulation
- Short-Term and Long-Term Leak Repair Testing. Long-Term testing included:
  - Thermal cycling (hot-cold testing)
  - Corrosion Salt-spray testing
  - UV exposure testing
  - Field Pilot Study

Results/Status

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

Short-term testing of the different leak-sealant products was conducted. This testing consisted of applying the sealant product to one-inch diameter 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.

In Phase 2, researchers tested and evaluated three "putty & wrap" style leak-repair methods for their ability to repair small-thread leaks typically found on the low-pressure side of an MSA (i..e 7 inches water column and 2 psig). The procedures for installing these leak-repair systems were developed through testing and in collaboration with manufacturers. All three leak-repair products yielded positive results during testing.

Phase 2 of this project also involved a field pilot project with gas utilities where crews tested these leak-repair systems by repairing natural gas leaks in the field. The project team created installation instructional documents for the three leak-repair products and also made instructional videos that demonstrate the leak-repair procedure of each product. Feedback from the field pilot study indicated that one leak repair product was preferred over the other two.

In Phase 3, tests were first conducted on the preferred "putty & wrap" style product from Phase 2 at elevated pressure to simulate leaks on the high-pressure side of a service regulator (~0.04 scfh at 60 psig). However, this leak repair product was found to be not effective at repairing higher pressure leaks. An alternate product for sealing elevated-pressure leaks was then considered and evaluated: a self-fusing silicone rubber leak repair tape. This product was tested successfully at repairing live leaks on test pipe fitting specimens at 60 psig air pressure. This product also performed successfully under long-term testing conditions which included: extreme temperature cycling, corrosion salt-spray testing, and UV exposure testing.

A Phase 3 Final Report was issued in November 2023.

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OTD Operations Technology Development

Noncamera-Based Technology to Detect Cross Bores

The project aims to develop a reliable and cost-effective tool for detecting legacy cross bores. This involves identifying viable technologies and evaluating prototypes to mitigate the risks associated with cross bores in utility systems.

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.

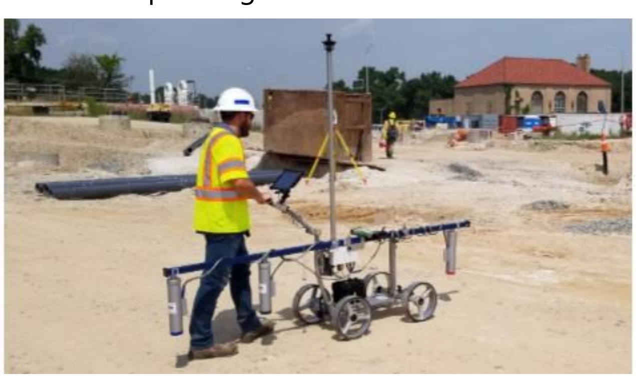
The objective of this project is to develop a tool to detect legacy cross bores. To achieve this, research is focused on identifying viable technologies and evaluating prototypes that can lead to the development of reliable and cost-effective cross-bore-detection tool for legacy trans-sections.

Deliverables

This project will deliver a summary report with an updated list of technologies for cross-bore detection, results of an evaluation of micro-impulse radar technology, and prototype development details.

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.



AM Gradiometer prototype

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.

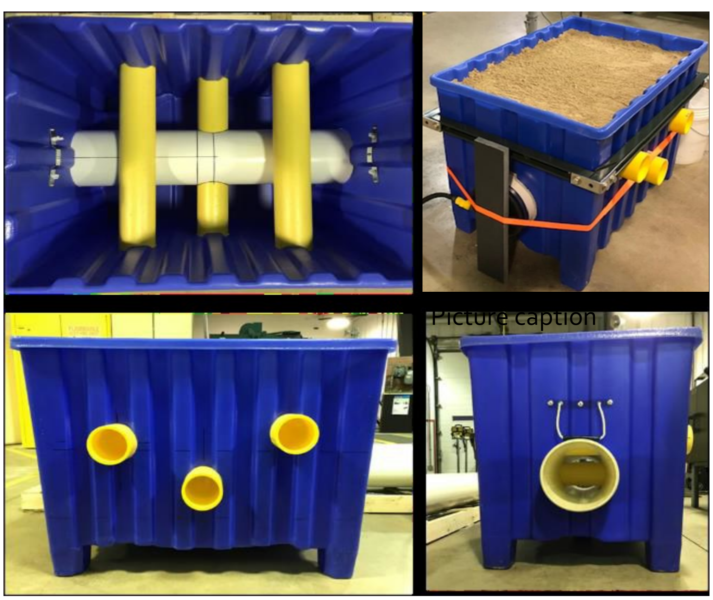
Results/Status

The team identified and evaluated several viable technologies.

Ground Penetrating Radar (GPR) is used to locate buried assets such as pipelines without excavation by using radar pulses to image the subsurface. GPR can be used for detecting legacy/latent cross bores by locating pipes and laterals through ground-level scanning, without requiring excavation. Several factors affect GPR's effectiveness, including soil moisture content, topography, noise sources, and operator skill level. GPR is cost-effective, enhances inspection efficiency by enabling large area scanning faster than camera solutions, and commercially advanced GPRs are available with 3D imaging and information fusion capabilities. GPR requires a skilled operator to interpret the response signals. A case study showed GPR had an 83% success rate in detecting cross bores.

AM Wave Gradiometer (AMG) technology uses radio electromagnetic waves such as AM-band radio waves to identify underground utilities of moderately low to high electrical conductivity. AMG is a passive sensing technology that can penetrate through concrete, rebars, pavers, and asphalt, and is less affected by high clay content or moisture in the soil. AMG can detect underground utilities at depths up to 30 feet. This technology is still under evaluation, with potential limitations due to varying geological and soil conditions. AMG offers higher depths of detection without requiring excavation and easier interpretation of results, but it is not commercially available and cannot differentiate between closely packed utilities. Further field trials and evaluations are needed to determine the technology's effectiveness.

Electromagnetic (EM) Thru-Pipe Sensing detects changes in dielectric properties of materials with small form factor hardware. This technology involves deploying an EM sensor inside gas mains/laterals to scan a predetermined length of the gas line. The EM sensor detects significant changes in the dielectric properties surrounding the pipe, such as a transition from soil to water/air, indicating a potential cross bore. EM sensors operate at a wide frequency range and provide high accuracy in detecting cross bores. The sensor must be placed inside the plastic gas pipe, which increases the complexity of accessing active pipeline networks. EM sensing technology is



Test bed used for sensor evaluation

Latro-3D GP Radar

not yet commercially available and is sensitive to field conditions. It also requires minimal human intervention and training requirements.

Acoustics-based technology can be used to locate cross bores by determining the depth of sewer laterals using sound waves. This approach involves injecting an acoustic signal into the sewer and using surface sensors to detect the lateral position and depth. Alternatively, a microphone placed inside a suspected gas line can detect the sound, indicating a cross bore. However, this technique requires a clean sewer line and access to the gas pipe, necessitating service disruption. While it has a relatively low cost of equipment and minimal training requirements, it needs significant improvements in accuracy and simplification of the operating procedure to be practical.

This project has been completed and a final report has been shared with OTD members.

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Operations Technology Development

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.

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

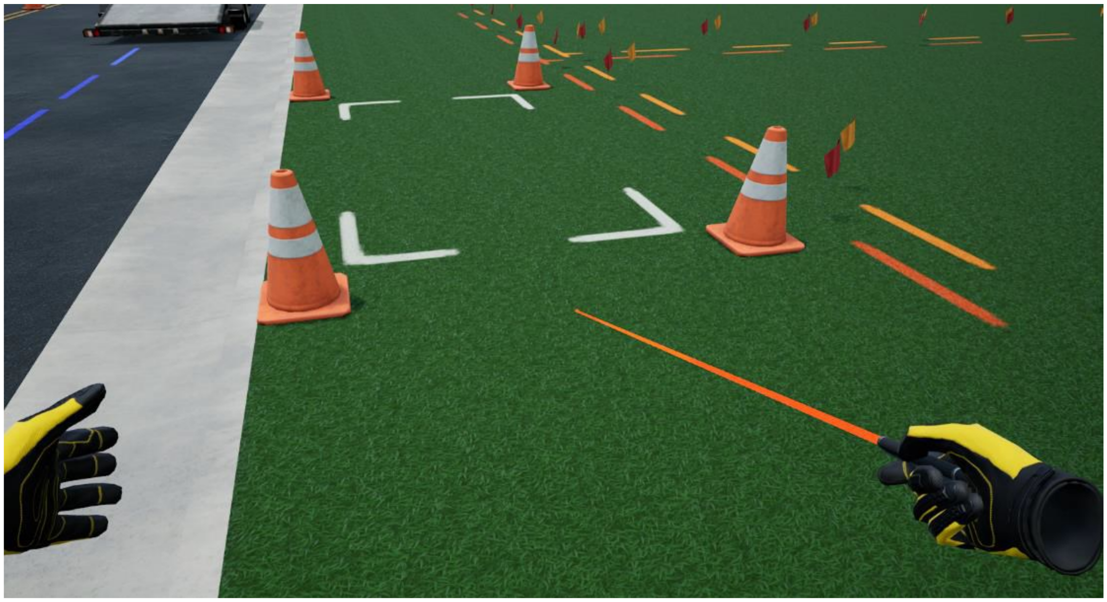
Benefits

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 scenarios to grow their experience and critical thinking in a safe environment.

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.



A variety of modules are being developed.

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.

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

In 2023, Oberon Technologies published the remaining virtual training experiences (VTE) to the platform on October 11th. All eleven modules are now available for use by those with platform licenses. The draft final report is actively being worked on to detail these 11 VTE's and the new features and functionality of the platform. A Final Report was delivered.

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OTD Operations Technology Development

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 pipeline. However, improper squeeze-off may cause damage to the pipe or create a safety hazard.

When performing a squeeze, a gap in the pipe may appear. A large gap may limit an operatora ability to obtain proper flow control. Conversely a small of a gap could lead to over compression of the PE pipe.

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 as a quality control check on both new and used squeezers to verify if they are within the required tolerances. It could also be used during field operations.

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

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
    - o The development of a series of validation/ inspection tools to measure the gap stop of PE squeezers for various pipe diameters, and
    - o 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 identify any existing processes for determining and checking the gap stops. Researchers also investigate various squeeze tools. This included the inspection of currently used field tools at various utilities and the inspection of new tools direct from various manufacturers.

Results/Status

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 identified tolerances to minimize or eliminate compression of the pipe walls. By fabricating the gap stop tool to these tolerances, operators can verify that the squeezers are acceptable if fully closed to the squeeze tool 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 on a PE pipe. However, the gap stop tool still can be used as a quality check, such as for operator qualification, new and old tool inspections, maintenance, and, if required, before actual use of the squeezer.

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.

Sample tools were manufactured and sent to project sponsors for evaluation and feedback. The tools can be custom fabricated using the determined dimensions, calculated by GTI Energy based on the size and SDR of the pipe and tubing that is being used. Additionally, the gap stop tools could provide an invaluable resource for training employees in the use of squeeze tools.

The Final Report was issued in February 2023.

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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 an 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. In this project, research is being conducted to find alternative methods of purging gas pipes into service to reduce overall methane emissions.

One alternative is using a vacuum pump. This process pumps the air out of the pipe. Once the proper vacuum level is reached inside the gas pipe, with the purge vent closed, the natural gas is introduced into the pipe without the need to vent.

High-priority issues being addressed include:

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

Deliverables

Comprehensive reports that describe the current vacuum-purging practice to minimize the venting of natural gas to the atmosphere.

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, gauges, connector kit, etc.

Once the field-ready version of the vacuum system is configured, researchers and project sponsors plan to conduct live demonstrations at utility-sponsored sites. 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 industry. Researchers 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.

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 and an additional 700 feet of two-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.

Phase 2 was initiated in 2021 when the research team completed the test loop of PE pipe in a pipe farm. The system also contained various valves, utility purge fittings, and purge stacks for various evaluations and verifications.

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. After several successful purges, the team introduced natural gas into the system.

The team conducted a live demonstration in the GTI Energy pipe farm which was also successful at achieving a complete natural gas purge without venting gas to the atmosphere.

A new vacuum system was also modified and tested. Modifications included adding a power supply and also reconfiguring the frame of the cart system to make it more maneuverable.

The team demonstrated the vacuum purging system in the field with OTD members. All of these purging pipes demonstrated the system's ability on the newly installed section of pipes and provide sufficient gas concentrations at each purge end almost instantly. The team is also continuing to review and modify the vacuum purging operations procedure.

Status

The research team is working on completing the draft final report. The team is in the final stages of negotiations with a commercializer and continues to perform field demonstrations with the OTD members.

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Review and Evaluation of the Utonomy Smart Regulator

Researchers are now looking to conduct field demonstrations of the Utonomy Smart Regulator for medium and low-pressure gas distribution systems with interested OTD members. The fine grained control provided by this regulator has the potential to reduce gas leakage and loss.

Project Description

The manufacturer of the Utonomy Smart Regulator claims that it is an intelligent monitoring and control platform for medium and low-pressure gas distribution systems that will provide continuous, real-time, visibility, autonomous control, and adjustment of pressure regulators and system pressure in response to changing gas delivery needs. The Utonomy 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 district regulator stations.

In this project, researchers will conduct field demonstrations of the Utonomy Smart Regulator for medium and low-pressure gas distribution systems. In Phase 1 researchers captured case studies of the SGN pilot installations and evaluated the Utomomy smart regulator system. In this phase, researchers will test the Utonomy Smart Regulator at Fisher's Flow Laboratory in McKinney, Texas and in North American utility field trials in order to demonstrate and validate its operation and benefits.

Deliverables

Deliverables for Phase 2 of this project will include: a review of sponsor needs, system requirements, how OTD members currently perform pressure regulation, and the potential for the Utonomy Smart Regulator to enhance that operation, an interim report on the Fisher flow lab test results, reports for individual field trials, and a final report.

Benefits

District governors regulating the pressure in natural gas distribution systems are typically manually adjusted on a seasonal basis 2 to 4 times per year and also most still use manual charts collected and replaced routinely to monitor inlet and outlet pressures. Some systems have remotely monitored and controlled pressure regulation, but company personnel must operate these systems 24 hours a day.

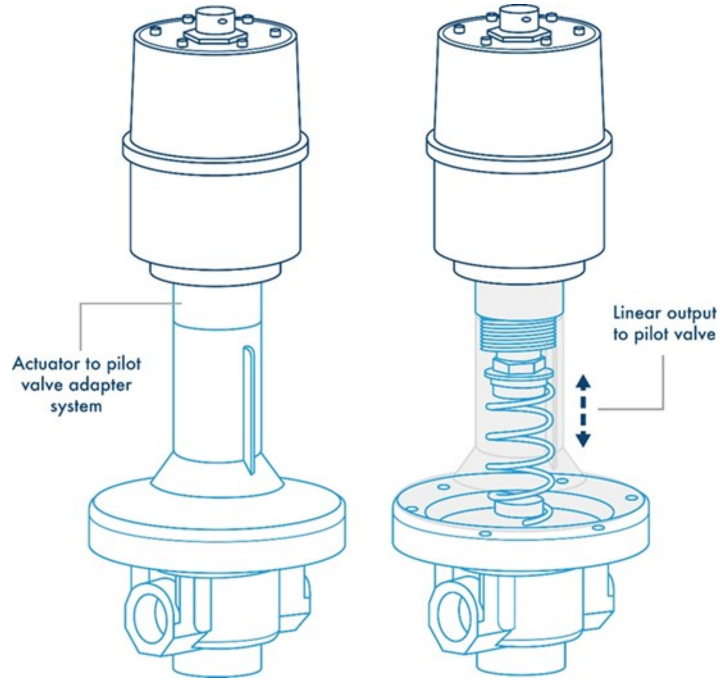
The use of the Utonomy Smart Regulator can provide operators with remote visibility of the operations of their regulator stations and signal failures immediately and has the potential to reduce gas leakage in medium and low-pressure gas distribution systems while increasing safety.

Technical Concept & Approach

Research and Evaluation

Evaluate the regulator pressure control system designs and control schemes currently (or planned to be) used to monitor and maintain the required system pressures. Tthis information will be used to validate the need or opportunity for the Utonomy Smart Regulator.

The Utonomy Smart Regulator will also need to be reviewed to see if it can meet the requirements for use in North America, (including analysis of remote communication, IT security, and power requirements & management), as well as to see if the Utonomy Smart Regulator meets relevant industry standards and certification requirements for the design and operation of pressure regulator station components in the US.



Laboratory Tests

Tests of the Utonomy Smart Regulator Pilot Actuators at either the Fisher Flow Laboratory in McKinney, Texas or at a mockup test setup at a utility site will be performed. This includes testing of the actuator assembled on both Fisher Y600 and 161 pilot regulators on a mockup pressure regulator station.

North American Field Trials

The project team will survey sponsors to determine interest in conducting field trials encompassing a 12-month seasonal cycle.

Results/Status

The project team developed and distributed a Utonomy Smart Regulator North American Market and Application Study Questionnaire. From this information, the project team has developed a gas industry needs analysis and validation in order to provide Utonomy with the necessary information to enhance their Smart Regulator system for North American gas industry needs and applications.

The team built and tested a prototype adaptor and completed enhancements for the Fisher Y600AM and the Fisher 161EMB-1 actuator.

The team tested the Utonomy Smart Regulator system on both a Fisher Y600AM and 161EB1 pilot regulator at an operator's service center. The team compiled the results and issued a draft final report.

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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.

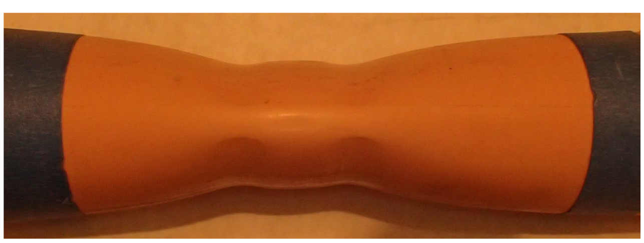
Project Description

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.

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 including rock impingement, soil loading and earth settlement, pipe bending, and squeeze-off.

Deliverables

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.



Specimen 222219-005 post squeeze at 0°C (32°F)

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

Specific tasks include:

Specimen Acquisition

Acquire samples for testing including 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

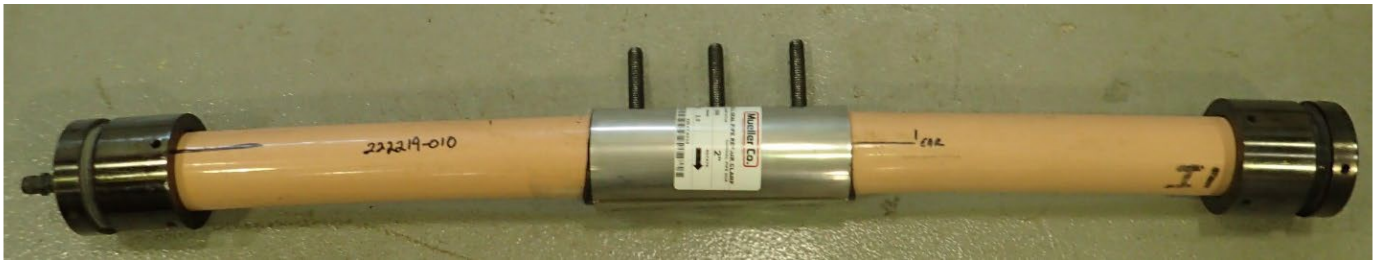
Validate the impact to a pipeline that is squeezed-off. Perform pipe squeeze-offs at different temperatures and under the typical operating pressures.

Material Properties Testing

Perform material properties testing via tensile testing and Dynamic Thermo-Mechanical Analysis to support the FEM analysis. For each of two pipe material, test three replicate specimens at three temperatures.

Short-Term Validation Testing

Prepare and test the squeezed-off pipe samples that



Exemplar squeezed specimen with Mueller clamp prepared for LTHS testing

were 3D scanned. Include a total of 36 specimens for each pipe size/material combination in the testing. Subject the squeezed-off and clamped pipe specimens to elevated temperature sustained hydrostatic pressure testing to validate a desired lifetime at end-use operating conditions.

Results/Status

Three common pipe reinforcement clamps were applied to squeezed-off, vintage Aldyl-A pipes. The pipes were X-ray/CT scanned to establish, in detail, the stress intensification factor (SIF) range that results from squeeze-off.

All of the reinforcement clamps prevented the pipes from failing at the squeeze-off location (where the clamps were applied), and all of the non-reinforced pipes failed at the squeeze-off ears.

Testing yielding an unexpected result were the non-reinforced (control) pipe samples exhibited marginally better lifetime expectancy than the reinforced pipes. The team’s hypothesis is that pipe ageing is the dominant factor in the remaining lifetime of the Aldyl-A pipes tested in this project. There is typically a large variance in ageing related times to failure in long-term hydrostatic testing. Given the limited number of pipe samples tested in this project, the apparent difference between reinforced and non-reinforced pipe could flip with more data development.

Reinforcement clamps are effective at preventing slow-crack-growth failures at the location where they are applied, and do not appear to have a detrimental effect on the pipe near the clamps.

This project is complete and a final report has been shared with OTD members.

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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, 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 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.

Despite these results, ultimately, the designs developed and further tested did not successfully meet the criteria of sealing leaks at the minimum target pressure of 60 psig. Although the project itself did not result in a tool design which met the seal criteria, some of the design elements were successfully incorporated into a different leak seal tool design with the SMP Project 22609.

Status

The Final Report was issued in December 2023.

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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.

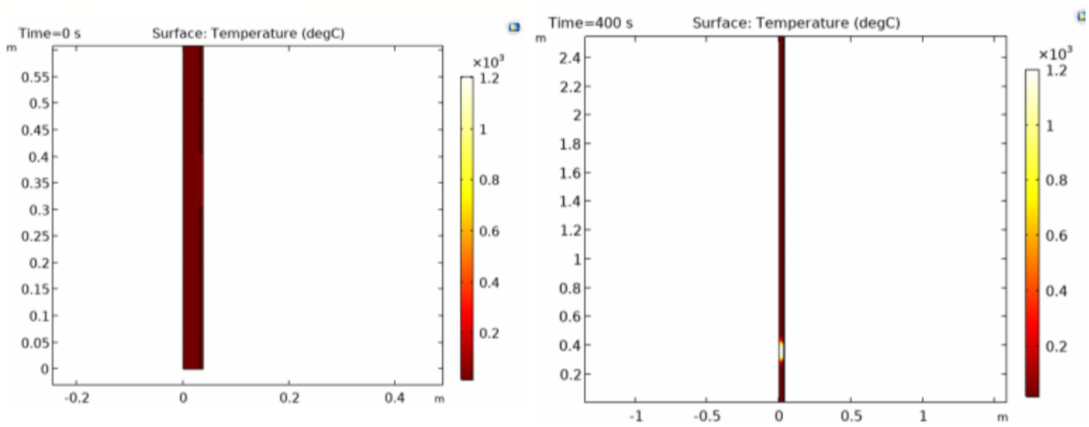
If existing material data is deemed insufficient, the materials of interest (steel and PE) will be tested for their heat-transfer properties – thermal conductivity and heat capacity – to ensure accurate simulations. Simulations will determine how long it would take for PE components to become overheated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

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



Heat transfer analysis.

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.

The heat-transfer simulation had the 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.

Throughout most of 2022, the project team continued to fine-tune the conjugate heat transfer Multiphysics model and started planning for the validation testing which commenced in 2023. The project team performed a “hot-squeeze” validation test for the purpose of validating the COMSOL simulation model. The test obtained valuable temperature information along the pipe of the test apparatus, and insight into the residence time of the hot gas slug once flow is initiated.

In the first quarter of 2023, the project team performed a second “hot-squeeze” test for the purpose of validating the COMSOL simulation model.

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.

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OTD Operations Technology Development

Subsurface Multi-Utility Asset Location Detection

Efforts are being made to develop an intrinsically locatable polyethylene (PE) pipe that would be easy to locate without the need to install tracer wire. 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 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, most commonly through the use of a tracer wire (coated copper wire) installed alongside the pipe, however, 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 limitations in certain soil types.

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

The research team successfully developed an integrated electronic marker to provide locatability to coiled or stick plastic pipes for gas and other utility applications. 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.

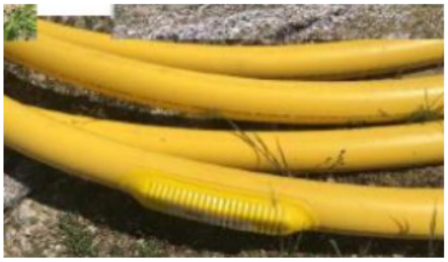
Deliverables

The project is aimed at delivering a pre-commercial product, 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

Advantages of an intrinsically locatable plastic pipe include:

- Enhanced safety for natural gas distribution networks
- 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

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 at the extrusion facility. 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 may include 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.

Results/Status

In 2023, the team recently produced 2" and 4" intrinsically locatable plastic pipe (ILPP) and this pipe was evaluated in GTI Energy's pipe farm through horizontal directional drilling (HDD) trenchless installations to create a tough real-world environment. The team used the HDD field installation results, prior laboratory adhesion results, and considerations for applying the tags in the extrusion process of the PE pipe to select the final adhesion options.

A manufacturer is now in the process of initiating designs and cost estimates for equipment and layouts to apply tags during the manufacturing process. In addition, the team recently completed a questionnaire and sent it out to OTD sponsors co-funding this project to verify some assumptions related to methods of installation, benefits, and estimated acceptable cost adders for ILPP systems.

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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 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
- 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.

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OTD Operations Technology Development

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:

- 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.
- 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.

Long-term testing rig.

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 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.

Tests of shut-off capability testing and communication were conducted. 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.

Later in the project, a "smart" residential diaphragm meter was added to the evaluation, as well as testing of additional safety aspect of the ultrasonic smart meter functions.

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 concluded in 2023.

Status

The Final Report was delivered in January 2023.

A follow-up project (5.20.e2), Single Path Ultrasonic Meter Long-Term Performance Testing and Monitoring: Pietro Fiorentini Ultrasonic meters was launched in early 2024

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Removing Water-Vapor Impurities to Improve Gas Quality in a Distribution Pipeline

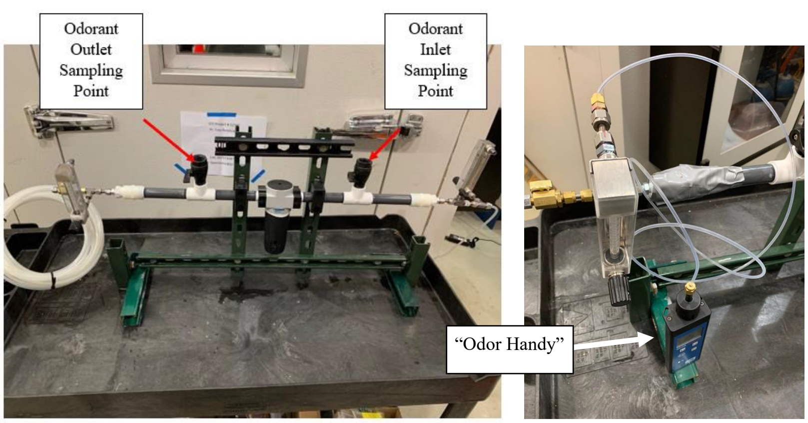
The objective of this project is to design and fabricate an in-line desiccating system that can remove water vapor in natural gas distribution assets. At the conclusion of the project, an in-line desiccating assembly will be provided to project sponsors.

Project Description

Water vapor may be present in natural gas distribution systems for various reasons and may condense and accumulate, leading to service interruptions and maintenance issues. Cost-effective moisture removal is needed to prevent equipment damage and assure safe and reliable operation. Desiccants are a low-cost option for water vapor removal as they are relatively simple and do not require additional energy input for the moisture removal process. The purpose of this project was to evaluate the efficacy of commercially available "off-the-shelf" desiccants to combat moisture buildup in low pressure distribution assets.

Deliverables

The final report which includes the results of tests with a selection of desiccant materials to evaluate odor fade will be provided to the project funders.



Odor fade testing setup (l) and Odor Handy measurement (r).

Benefits

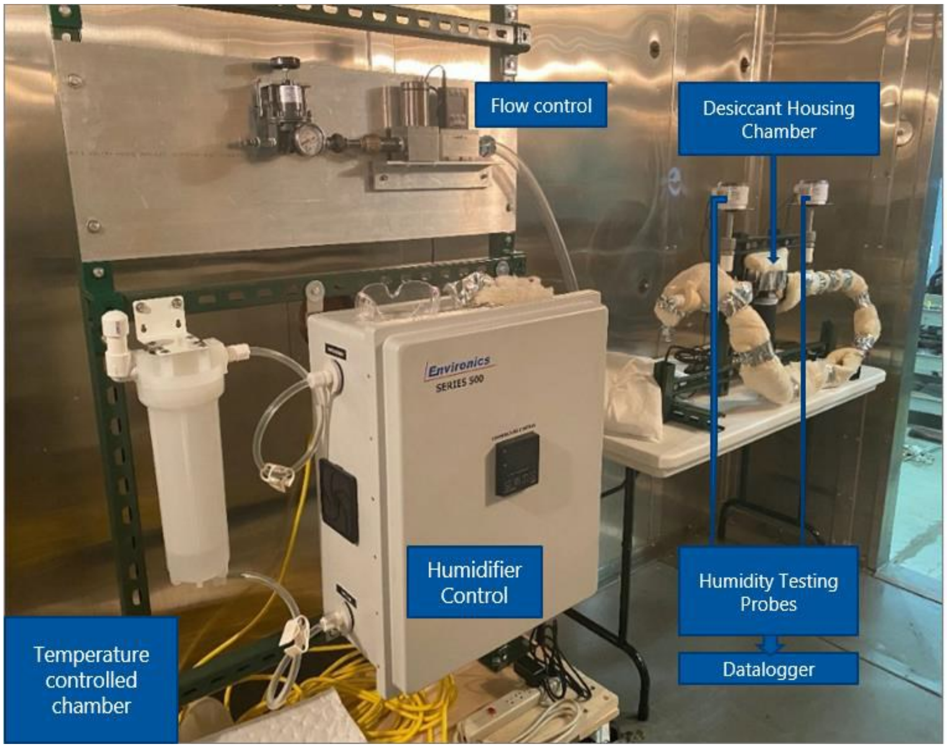
By better understanding passive, in-line dehydration concepts and desiccant materials, recommendations can be formulated for modification of existing equipment and development of more advanced desiccation systems. If proven effective, in-line desiccant assemblies can help prevent equipment damage and operational issues that threaten safe and reliable operation.

Technical Concept & Approach

Primarily focused on residential customers, a simple desiccant-based dehydration system would streamline maintenance related to moisture management. Passive dehydration systems use a solid desiccant media to remove moisture. The desiccant material is contained within a housing or vessel through which the gas flows to remove moisture. This was the basis of the experimental setup using humid air flowing through a desiccant housing to evaluate moisture removal performance.

Results/Status

The team chose a general sampling of desiccant products for investigation. Prior to testing for moisture removal performance, each desiccant was evaluated for their capacity to diminish Tert-butyl Mercaptan (TBM), the primary compound added to natural gas to provide odor indication. Two of the initial seven desiccants were chosen for additional testing.



Water Vapor Removal Test Rig

An experimental apparatus was constructed to emulate conditions of a gas distribution system, though much higher humidity levels were employed. The system included a humidifier, environmental control chamber, and a vessel to house a small amount of desiccant for testing.

After screening for odor fade resistance, two desiccant samples with the least odor fade were selected for moisture removal testing. To accelerate testing, the selected desiccants were tested at high humidity (near saturation) over a range of pressure and flow rates. Both desiccants tested removed water vapor and performed at or above manufacturer's standard for moisture saturation weight gain..

This accelerated testing of desiccants was performed with humidity levels approaching saturation. While this enables a comparison among desiccants in laboratory conditions, it is not reflective of operating conditions where humidity levels are much lower. In practice, desiccants exposed to lower humidity would be expected to last much longer. The duration of service before desiccant changeout is needed would depend on flow rates, temperature, moisture conditions and operational concerns.

The learnings of this project led to a better understanding of how passive desiccant systems might function for this application, and steps to further advance the design of a prototype for field deployment. Phase 2 of this project, which will begin in 2024, aims to develop and test a desiccant system for moisture removal.

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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 stand-alone 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.

This project 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.

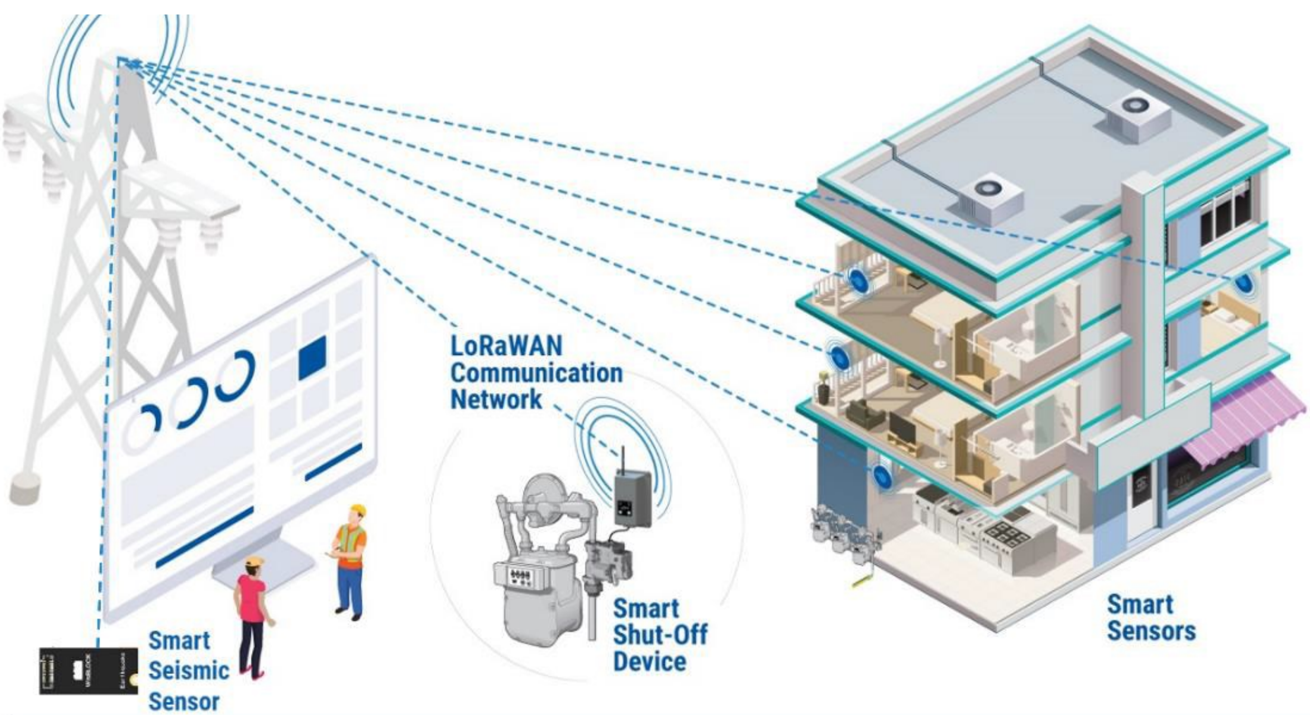
The system will consist of the four basic components:

Smart Sensors, Devices that can be placed inside or outside a structure. When these sensors find an abnormal condition they will send an alert that can be received by other smart devices, including an automatic gas smart valve.

Smart Shutoff Valve: An automatic valve that is connected to smart sensors that can stop the flow of gas into a structure (or appliance).

Communication Network: Communication platforms that connects the operator with the smart sensors and smart shutoff valves.

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.



Smart Shut –Off system

Deliverables

Deliverables for this project include the final Customer Research Plan, and a demonstration of 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/Status

Two prototypes were developed and tested at three OTD member sites. These systems successfully exhibited desired behaviors including leak detection, automated flow termination, and real-time control, monitoring, and reporting. The two prototypes were developed by different vendors and both systems incorporated smart sensors, demonstrating the flexibility and interoperability of LoRaWAN technology.

Winters Demonstration Site

The demonstrations confirmed the intended functionality of the systems, including remote and Device-to-Device (D2D) disconnect capabilities. Preliminary data indicated low latency for both remote and D2D disconnects, averaging less than 75 seconds.

While the demonstration systems were left with OTD members, field trial data was not available at the time of the report. However, performance assessments were conducted using field trial data from an operator's independent LoRaWAN evaluation. This evaluation showed robust network performance with high Packet Success Rates (PSRs) for both uplink and downlink communication, low latency, and successful interoperability of different end-devices. Battery life analysis indicated a replacement cycle approaching 20 years for both the smart shutoff valve and the smart gas meter with built-in shutoff valve.

This project is complete and a final report has been share with OTD members.

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Product Performance and Validation Program

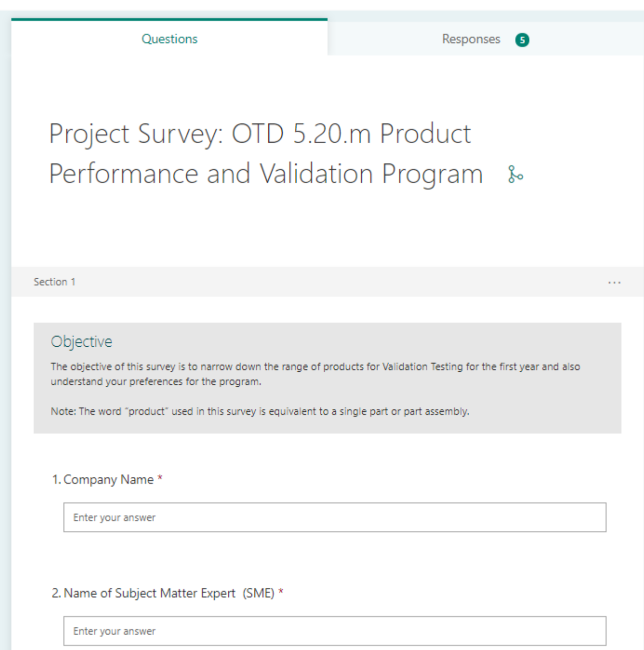
For this project, researchers are creating a program to validate gas-industry product performances to confirm that manufacturers still produce high-quality material meeting customer and industry requirements. The program compares performances of similar products from various suppliers to help in making informed decisions for their continued usage.

Project Description

Requirements to validate product performances at the design level are well-defined in various industry standards.

However, gas industry standards, with some exceptions, do not require validation of processes due to continuous changes throughout a product's lifecycle in commercial manufacturing settings.

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. 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.

During Phase I and Phase II of the program, the GTI team tested electrofusion fittings of various suppliers, 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
- Tensile or impact

The testing plan included 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.

During Phase II, the GTI team also tested PE Mechanical fittings (Category 1) from two different vendors, following the requirements of ASTM F1924.

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Results/Status

The project team submitted a survey to project sponsors in October 2020 and in December 2022. The survey asked a series of questions to narrow the range of products for testing.

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.

All tests for electrofusion couplings and tapping tees have been completed.

All tests for mechanical fittings have been completed.

The final report has been drafted and is being reviewed before submitting to sponsors

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OTD Operations Technology Development

Product Performance and Validation Program

The objective of this project is to create a program to validate product performance through testing to confirm that the manufacturers produce high-quality material meeting industry requirements. The program will compare the performances of similar products from various suppliers to help make informed decisions.

Project Description

The requirements to validate product performances at the design level are well defined in the industry standards. It includes comprehensive testing protocols, and methods products need to be subjected to before introduction to a market or when critical changes to a product design or material occur. In the commercial manufacturing environment, production processes (equipment, technology, etc.) throughout a product's lifecycle are constantly changing. Product performance is affected by these changes and can be detrimental to its fit and function if not validated.

Based on the observations made during the last eight 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 to ensure that process and product changes have no detrimental effect on its fit and function.

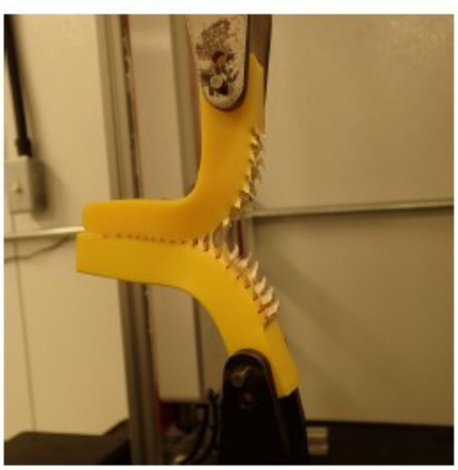
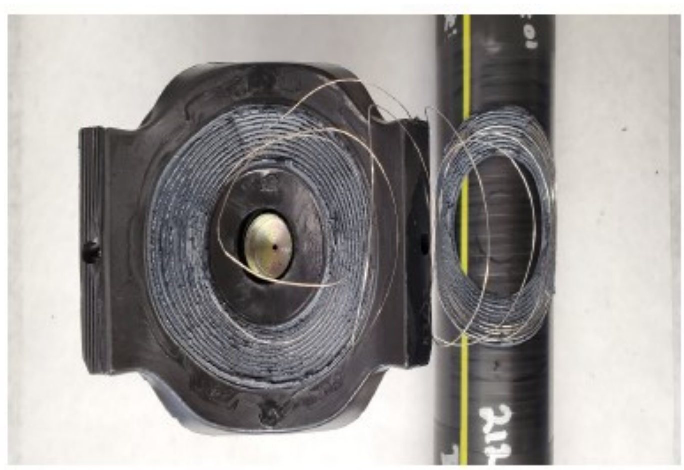
Deliverables

The deliverable for this project will be a final report of an individual set of tests by product type and a comparison of product performances.

Benefits

Participation in this program will provide value in the following ways:

- Create efficiencies and cost savings by consolidating testing of products shared by the sponsors.
- Assess if products meet the requirements of the industry standards.
- Provide information to sponsors on product performance to make more informed choices.

Examples of tests

- Provide information to sponsors that can be used to evaluate their suppliers.
- Provide test results to sponsors to approve a new supplier.

Technical Concept & Approach

The customers select the potential candidates for testing via surveys. GTI Energy team then creates a testing matrix based on the qualification requirements of a product's pertinent standards and conducts tests. Sometimes, tests are subcontracted to accredited laboratories due to schedule conflicts or equipment limitations.

Results/Status

During 2023, the project team completed the preparation of the electrofusion and mechanical joint assemblies. Initiated a number of tests per ASTM F1055 and ASTM F1924 to evaluate the electrofusion joints and mechanical joints, respectively. This project is delayed due to supply-chain issues with installation tools for Lycofit mechanical fittings, the long lead time to perform the Constant Tensile Load Joint test, and issues with the Impact tester.

The project is anticipated to be completed in Q2 of 2024.

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Examples of tests

OTD Operations Technology Development

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

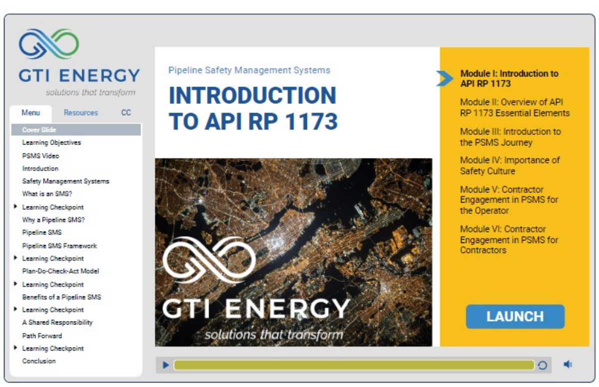
The deliverables from this project will include:

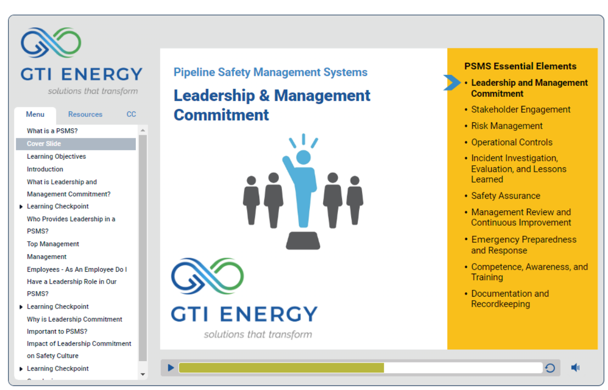
- A Final Report detailing the training content developed and the process followed for developing the training.
- Access to training material, including:
  - Training needs assessment from project sponsor subject matter experts
  - An instructor guide for delivering developed training content
  - Handouts for new training content
  - Computer-based training modules, and
  - Access to a delivery platform.

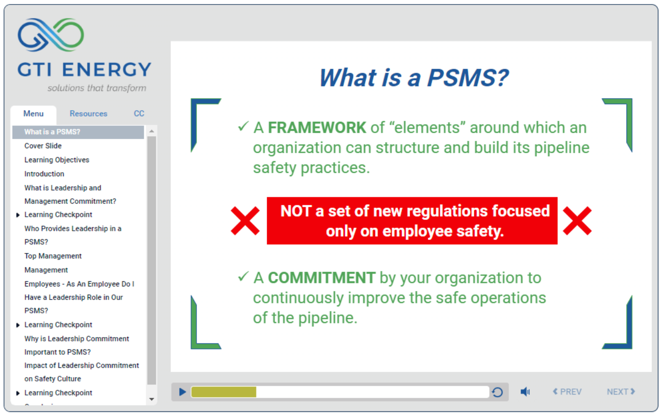
Benefits

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.

All seven modules were developed:

- Introduction to API RP 1173
- Essential Elements of API RP 1173
- PSMS Journey
- Contractor Engagement (Internal)
- Contractor Engagement (External)
- Importance of Culture
- Leadership Commitment.

Status

All seven modules have been published to OTD project sponsor learning management systems.

The Final Report was delivered in January 2023.

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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.

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, 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 creating downstream gas leaks on customer piping due to the excessive stress and strain created from pipe wrenching activities required to unseize these fittings. This tool will improve employee and customer safety along with reducing time required to repair customer piping leaks created by LDC employees 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 worked with the tooling manufacturer to review the commercialization process for this phase.

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.

Work continued throughout 2022 and in 2023, the GTI Energy design team worked with its external partner to refine several critical tool features, primarily the quick-release mechanism for the drive screw along with the clamping mechanism which holds the tool in place against the meter inlet and outlet piping. Since the kickoff in 2021, the project team has initiated the development of 12 iterations of the prototype.

The idea for a quick-release mechanism grew from a desire to make the tool easier for the user to operate. The team observed during testing of Prototype #10 that there should be a quicker easier way to go from the end of one stroke of the tool to the beginning of a new stroke. There was also a need to get the drive screw into position quicker when initially setting up the tool and wrench. The design team fabricated and tested several modifications to Prototype #10 until settling on a design based on an existing mechanism. This latest quick-release design is now incorporated into Prototype #12 for testing.

Status

A new phase of the project has been awarded to continue to refine the tool design and then move into commercialization/production with our partner. This will kickoff in Q3 2024.

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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 of time and material required to make repairs, these damages create risk to responding employees, the general public, and property.

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 damage 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 are a final report detailing the training content developed and the process followed for developing the training, access to training material developed, including: training needs assessments subject-matter experts; an instructor guide for delivering developed training content; 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, 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.

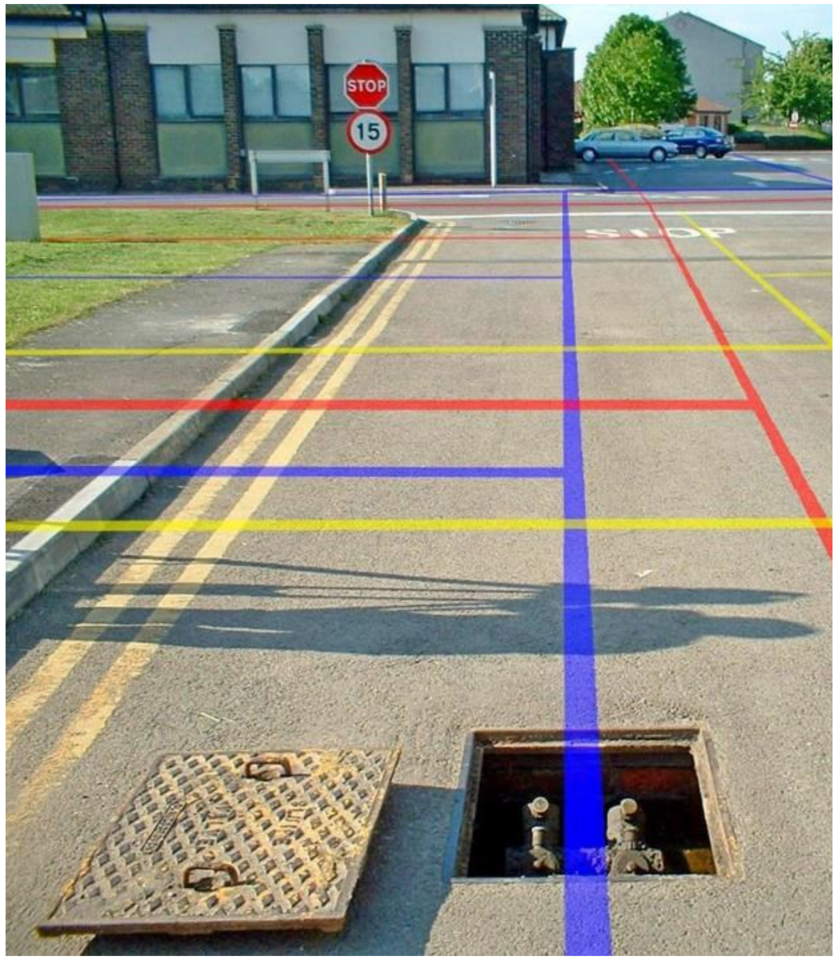
This type of training can also be delivered on-demand to external stakeholders without requiring access to a learning-management system.

Technical Concept & Approach

The project team will initially identify the training

Example of Facility Overlay for 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).



Example of Facility Overlay for Training

Results/Status

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.

Feedback received indicated that 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.

A GTI Energy subcontractor completed development of the computer-generated VR training experience; this experience was published to the content distribution platform on June 30, 2023. The recently published module is currently being tested using VR headset devices and on standard laptop and desktop computers.

A final report is in development.

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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

It is recommended that existing interior service regulators be relocated outside whenever the gas service line, meter, or regulator is replaced, but sometimes it is not possible. There may be no outside space for a gas service regulator or municipalities may have restricted outside piping. In these situations, devices may be used in indoor regulators' enclosures 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 in order to provide an equivalent level of safety as compared to gas regulators located outside of the structure.

Deliverables

Key deliverables for this project include an evaluation of retrofitting and rehabilitation best 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 leaked from the piping systems may accumulate in a confined space. Many situations necessitate the installation of indoor regulators (many in meter rooms) where outside installations are not feasible or practical.

This project provided the actions required to investigate, rehabilitate, and retrofit indoor gas regulators and piping systems.

Technical Concept & Approach

Project tasks included:

Review of Current Practices and Technologies

Investigated and collaborated 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

Identified and reviewed 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. investigated smart shutoff valves that have the ability to incorporate methane sensors for improved safety.

Inspection and Rehabilitation of Regulator Piping Systems

Investigated potential leaks caused by piping systems, other than the regulators' venting events. Factors included pipe age, installation procedure, inspection procedure, piping support and placement, condition of the coating, and relative humidity.

Best Practice Guidelines and Recommendations

Developed best-practice guidelines for the installation, inspection, and record capture for inside regulators with the TAP and industry SMEs.

Results/Status

The team developed a report which covers:

Evaluation of Current Utilities Practices and Procedures

Local Distribution Companies (LDC's) have specific procedures that need to be followed by their field

Figure 35. Sensors' setup and data collection system

employees for the installation and maintenance of indoor natural gas piping. The LDCs procedures are based at a minimum on 49 CFR 192 requirements and other industry standards listed in this report. The team looked at Industry codes and standards for gas pressure regulators, LDC's indoor piping installation practices, installation requirements and procedures for inside meters and regulators, maintenance of inside meter sets. They interviewed LDC members for their retrofitting practices for Inside Regulators and placement.

Discussions with Subject Matter Experts (SMEs) and LDC operators showed that, from a Distribution Integrity Management Program (DIMP) standpoint, inside regulators pose a high risk to gas leaks and that the safety risk may be lowered by utilizing newer low-emission inside regulators, using 2-stage regulators with slam-shut features, and RMDs located in the area of company owned inside piping.

Monitoring and Retrofitting Indoor Regulators

There are new products on the market that can potentially be used to retrofit new or existing inside regulators and stop the flow of gas in the event of regulator failure. The team reviewed past projects on testing and evaluating these new technologies for their potential in stopping the flow of natural gas into a building in the event of a detection of a gas leak. The team's review includes comprehensive smart systems, smart shutoff valves, and low emissions regulators.

The team recommended the use of retrofitting indoor regulators with smart sensors. In these safety systems, smart sensors to detect methane, flood, fire, and gas line pressure are deployed in residential and commercial buildings for these potential hazards.

Evaluation of Recent Smart Retrofitting Technologies

Various technological improvements in regulator's design reduce hazardous gas from escaping the regulator and meter sets. Devices are being designed for smart shut-off technologies, to detect hazardous levels of methane, and to provide an alert system when these leaks are detected. The team reviewed studies on retrofitting inside regulators with smart devices, evaluations of Residential Methane Detectors (RMD), evaluations of smart shut-off valves, network communication for RMDs and smart shutoff valves, and two stage regulator systems. The team also conducted RMD testing and an evaluation of smart shutoff valves.

Inspection and Rehabilitation of Indoor Piping Systems

The team reviewed field monitoring studies, parameters affecting indoor piping condition, corrosion potential in indoor piping systems, and gas leak measurements in indoor regulators and concluded that humidity and the age of the pipe are the two dominant factors impacting corrosion.

Best Practice Guidelines and Recommendations

The team presented risk factors with their associated impact and probability considerations for a Risk Analysis for a DIMP, Data collection practices, and recommended Best Practice Guidelines .

This project is complete and a final report has been shared with OTD members.

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OTD Operations Technology Development

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 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 demNorth 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/Status

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.

Tablets are being distributed to participating pilot sponsors with installed software.

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Development and Evaluation of the CoSMiC Eye Satellite Based Pipeline Monitoring System (Phase 2)

Building off a previous OTD project, the objective of this project is to develop, evaluate, and demonstrate the CoSMiC Eye Satellite Based Pipeline Monitoring System to monitor activity along a pipeline Right-of-Way (ROW) for Class Location designation.

Project Description

Phase 2 of this project looks at testing the application of the CoSMiC Eye monitoring system for detecting changes in class location. The CoSMiC Eye satellite-based pipeline monitoring system uses both radar and optical imagery to detect potential threats in a pipeline ROW. Data delivery by these radar satellites is not impaired by weather conditions. After changes near the pipeline ROW are detected, they pass through several classification models to identify only those activities or changes in the ROW that are potentially relevant to pipeline operators (e.g. the presence of construction equipment, road work, structures, buildings, agricultural activity, etc.).

When the radar data indicates an activity in the pipeline ROW, the CoSMiC Eye system automatically tasks an optical satellite to acquire optical imagery for that site. For changes deemed relevant by the CoSMiC Eye system, an alert is issued to the pipeline operator. An example of this functionality can be seen in Figure 1, which was acquired during the recent Phase 1 OTD project demonstration. Viewing the changes to the site over time allows operators to be more proactive in identifying potential threats. Class locations are dependent on changes to operating pressures, as well as changes to human occupancy. Providing data that may show changes to human occupancy helps operators identify changes to class locations.

Deliverables

- Conduct monitoring of selected pipeline ROWs.
- Orbital Eye will provide training on implementing the monitoring of a specific pipeline segment, the operation of the CoSMiC Eye system, and training on collecting and interpreting the data and alerts generated by the CoSMiC Eye satellite monitoring.
- Technical support by CoSMiC Eye personnel during regular business hours
- Review and training of the CoSMiC Eye web-application for users.
- A report will be prepared on the results and conclusions of the field demonstrations of CoSMiC Eye that will be conducted by North American gas companies. This will include a review and analysis of the pipeline segment that was monitored.

Benefits

The CoSMiC Eye Pipeline Monitoring System has been developed as a low-cost satellite-based pipeline monitoring system that uses both radar and optical imagery to detect potential threats in a pipeline ROW. This system is currently being used by gas utilities in Europe, Canada, and the Caribbean. The system harnesses satellite data and machine learning algorithms to detect potential threats to the pipeline ROW and allows for the data to be updated more frequently and allows for operators to be more proactive in addressing potential threats and identifying if their pipe segment is changing class locations.

Figure 1: Example from the first phase, where construction activity was detected 225 feet from the monitored pipeline, over a period of 4 months.

Technical Concept & Approach

Based upon the success of CoSMiC Eye in monitoring pipeline ROWs for third party interference, the project team will use the CoSMiC Eye capabilities to monitor a larger pipeline ROW for existence of and construction of buildings for human occupation or congregation. The data developed by CoSMiC Eye pipeline monitoring will have impact on pipeline class location determination which will be used for future pipeline construction and design, MAOP determination, and operation and maintenance.

Results

There are currently no results for this project since field demonstrations have not started.

Status

Field trials were delayed due to the decision to avoid monitoring during the winter months, since construction is usually dramatically reduced. The project scope was revised to include both ROW monitoring and Class Location change monitoring. Two operators have been selected to host demonstrations. The demonstrations are anticipated to begin in April 2024 .

OTD Operations Technology Development

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. Safety questions may still remain pertaining to 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, however that could potentially result in electrical 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.

The deployment of automatic metering systems has allowed for remote disconnects for electrical service. The assumption is that the remote disconnect contacts will be safely packaged to not present an arcing hazard exterior to the device. However, this assumption needs to be properly evaluated.

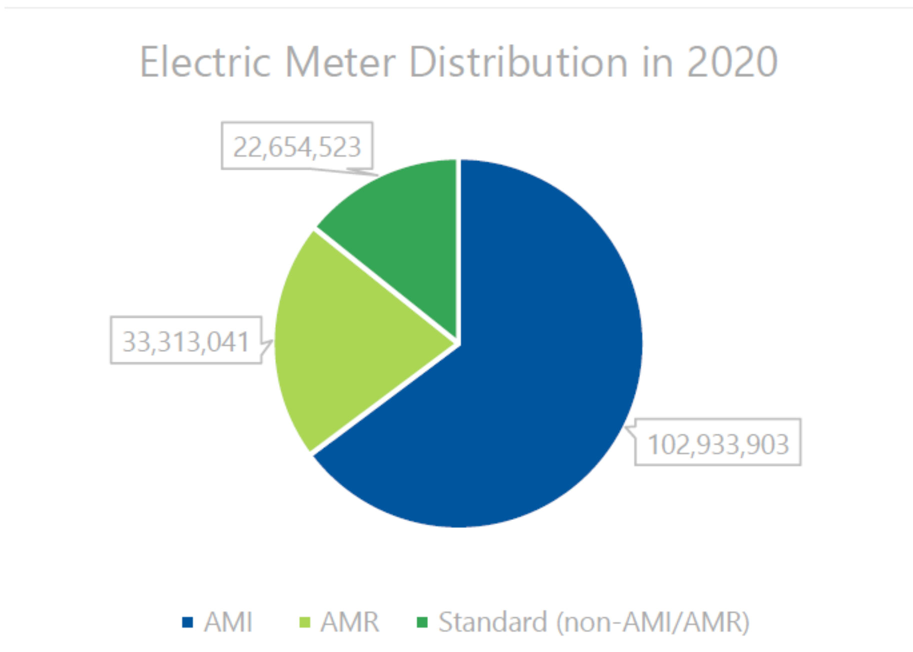
This project investigates the rapid disconnect of electrical service in the presence of elevated natural gas readings within a structure. Researchers for this project will evaluate the likelihood of ignition sources resulting from both manually pulling the electric meter and from using an automatic/wireless disconnect device.

Deliverables

The deliverables for this project will be 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/Status

The team found that existing smart electric meters with remote disconnect capabilities operate by breaking the electrical contact with a mechanical relay. The team determined that there is currently no evidence that remote-capable smart electric meters are safer than older electromechanical or digital meters without remote capabilities in the presence of combustible gas since the former also use electromechanical means of switching off the service. This is most likely due to the electric smart metering industry not being aware of such a need in the first place. Remote disconnect was implemented as a means of ending or limiting electrical service rather than as a safety feature.

There are possible scenarios in which disconnecting a service will not cause a spark with sufficient energy to ignite gas. The team developed graphs and analysis to demonstrate how the current and load inductance affect the energy of a spark, which occurs when contacts are separated, or "broken," in a circuit under load. These are included in the final report.

If there is no flammable gas within the electric meter housing, the presence of a spark is also not hazardous. During an emergency event it is practically impossible to have all the information necessary to guide that decision. Therefore, it is generally safer to disconnect the service from remote points that are away from combustible gas. In some scenarios service shut -off requests via remote capabilities may be an option, such as when the meter is located outside and the gas readings within and outside the premises are below LEL or where the leak is confined to a specific region of the building and is far from the meter. To reach a conclusive answer, lab testing is needed that subjects the electric meters to hazardous atmospheres and investigates the interactions of such atmosphere with the disconnect mechanism under load.

This project is complete and a final report has been shared with OTD members.

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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.

Among the types of equipment being tested.

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.

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/Status

This project identified two specialized valve keys on the market, which are specifically developed for use on damaged or rounded off square nut operators

Laboratory testing.

and evaluated their effectiveness against a traditional square valve key. The valve keys were evaluated in GTI Energy's lab using torque tests on simulated rounded off operator nuts to assess and compare their effectiveness in turning the operators.

Operators should consider the size and weight of the specialty key, which may be more difficult to carry in comparison to the standard valve key. The final report was issued in 2022 issued as an interim report because the initial field trial demos with two LDC operators did not yield sufficient survey results.

GTI Energy will attempt to conduct further field trials with additional operators and compile their results into a completed final report to be issued at a future date.

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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, with methane and methane/ hydrogen blend. This task also includes a visual examination to count any existing SCG (slow

The enclosing test, water tanks, gas cylinder racks, water heaters, water-conditioning system, and ventilation duct are all in place.

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/Status

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.

In 2023, the team completed long-term hydrostatic strength (LTHS) testing of Aldyl-A samples. Analysis of all the LTHS results in each test group suggests similar slow crack growth performance with 20% hydrogen blend versus methane. However, analysis within specific SIF bins (performance bands) suggests a 5-10% higher equivalent stress on the 20% hydrogen blend samples. Additional LTHS test samples are required to resolve this apparent contradiction. Testing of M8000 samples has been ongoing.

The final report for Aldyl-A testing is in progress, expected to be completed in June 2024. Because testing of the pipe samples is to failure, timing of the final report will depend on the amount of time it takes for samples to fail. Therefore, the draft final report for M8000 is tentatively expected for July 2024.

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Assessment of FFS Performance Envelope Reduction from Hydrogen Embrittlement

The objective of this project is to provide operators with an overview of the impacts of hydrogen embrittlement on fitness-for-service (FFS) of pipeline steels and how to quantify the potential impacts on their specific pipe materials.

Project Description

Sandia National Laboratory (SNL) teams have conducted research under the US Department of Energy (DOE) HyBlend project. Their results show the impact to performance of pipelines when hydrogen is introduced.

The impact to pipeline fatigue, strength and hydrogen embrittlement need to be better understood by operators and the impact of these to the pipelines FFS.. .

Deliverables

The project will deliver a final report that includes:

- Hydrogen Embrittlement (HE) performance envelope reduction assessment based on SNL's steel material data
- Discussion on the implications of HE performance reduction on integrity management
- Recommended material testing plan for input into hydrogen FFS assessments.

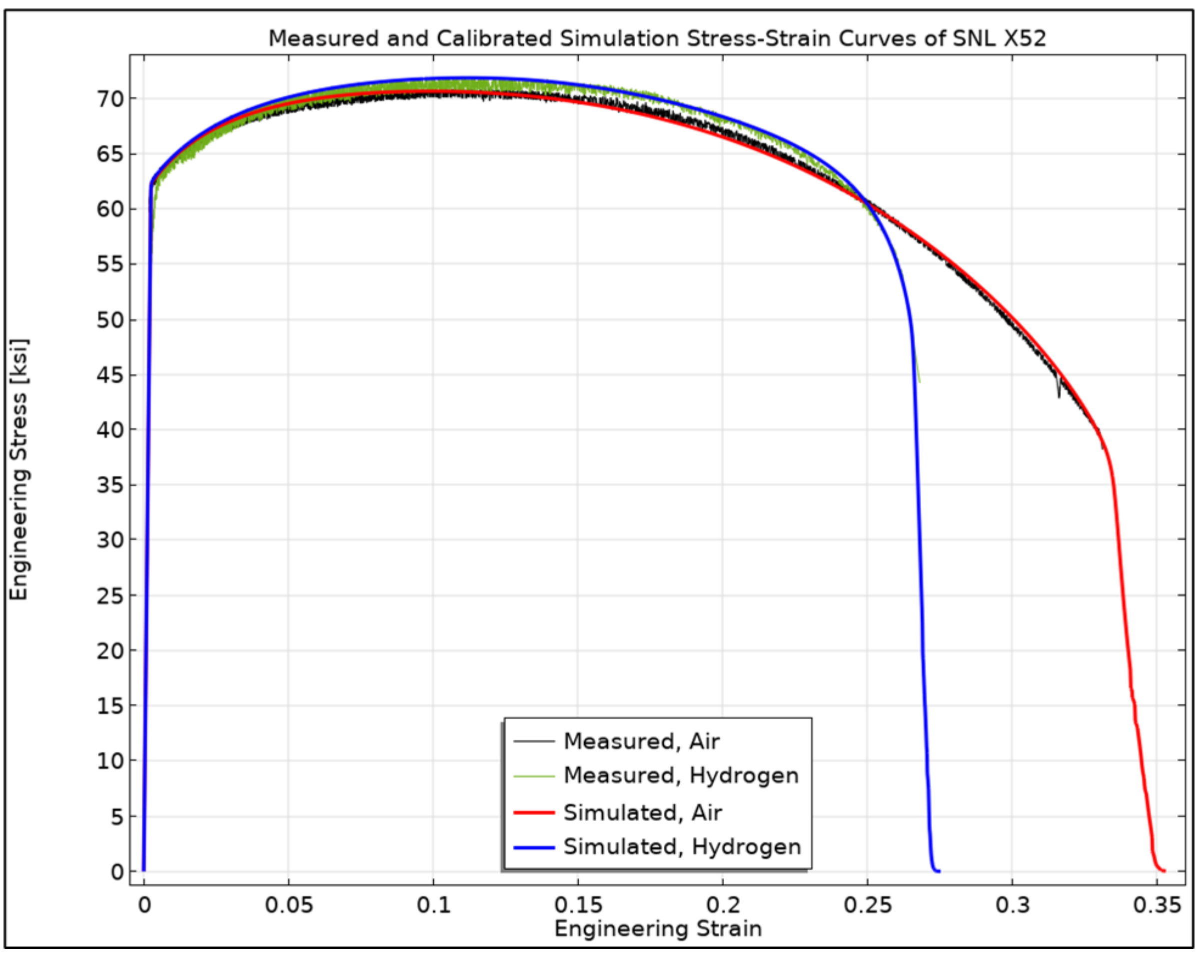

Figure 1. Measured and Calibrated simulation stress-strain curves of X52 material tests by Sandia National Lab (SNL)

Benefits

Quantifying the impact of HE on steel pipes is crucial for integrity management and regulatory compliance. The impact of HE needs to be fully understood by operators and a guide on how to quantify it and use the test data in FFS assessments will assist in engineering decisions related to integrity management of natural gas pipelines transporting hydrogen.

This project will provide an initial look into the impact of HE on the performance envelope of steel pipes using FFS assessments and steel material data already obtained by Sandia National Laboratory under the DOE HyBlend project. This work intends to provide meaningful insight and practical recommendations to facilitate the integrity management of steel pipes carrying hydrogen or natural gas/hydrogen blends.

Technical Concept & Approach

GTI Energy will use SNL's steel material data and perform an assessment to understand the impact of hydrogen embrittlement, based on established fitness-for-service calculations. The implications of the assessment will then be discussed and summarized to provide operators with a general overview of the expected impacts and how to quantify the impacts on their specific pipe materials.

Results

Test data from Sandia National Laboratory was reviewed in further detail, and mapping was initiated to capture the relationship between specific material properties, the tests conducted to obtain them, and the assessment methods that depend on those properties. The project team focused on developing an input matrix for Sandia National Lab's Hydrogen Extremely Low Probability of Rupture (HELPR) software tool.

HELPR is used to perform probabilistic fatigue and fracture analysis for pressurized cylinders. The project team's review of the solution confirmed that the software performs as intended and that it will be capable of supporting producing fatigue calculation examples.

Status

The Level-2 and Level-3 FFS assessments are in progress. Simulations are being executed to generate FFS calculations using probabilistically varied material properties.

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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 details regarding the hardware equipment, software and any licensing requirements.
- 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).

360° 3D high-definition video training example with informational hotspots.

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/Status

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.

Work continued in 2022 and 2023 as the following technologies were identified as potential training approaches: gamification, scenario branching training (also known as interactive storytelling), 3D augmented reality/ virtual reality models, 3D models with animations, micro-videos; computer-gnerated VR, desktop VR, where VR content can be displayed on the computer screen, and learners typically use a keyboard, mouse, or external controllers to navigate and interact with the virtual environment. This method is generally more accessible and cost-effective since it doesn't require specialized VR headsets. It is suitable for scenarios where full immersion is not a priority, but visualizing 3D environments and limited interactions are sufficient for the training objectives.

The final report was scheduled to be delivered in December 2023.

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Effect of Hydrogen-Blended Natural Gas on the Performance of Gas Meters and Diaphragm-Type Service Regulators

Researchers are examining the impact of hydrogen-blended natural gas on the performance of domestic gas meters through extensive, long-duration testing.

Project Description

With the proposed inclusion of hydrogen-blended natural gas into gas industry piping systems, 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 OTD 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. 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
- 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. They will be subject to the following tests:

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.

Results/Status

In 2022, the project focus was on designing the test rig and finalizing the equipment purchase and in 2023, the test rigs were constructed. There was a significant lead time on several of the electronic components required for the operation of the flow loops. The estimated ship date for these components was late 2023.

In 2023 the project team purchased the required components and will begin the installation of these components in Q1 2024.

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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 the design and performance of pipe-in-pipe (PIP) systems to rehabilitate natural gas pipelines in place and in service.

The project team developed analytical tools that can estimate the failure behavior of PIP and determine the appropriate thickness and required mechanical properties of structural PIP for repair of steel and cast-iron pipelines. Researchers advanced these analytical tools using Finite Elements simulations performed at University of Southern Queensland. Validation tests and the performance of the PIP system under external loads and internal pressures were performed at the University of Colorado Boulder and GTI Energy.

The project is co-funded by the U.S. Department of Energy's ARPA-E program to provide natural gas companies with alternative and safe structural repair systems. The OTD cost-share project focuses on performing laboratory tests to evaluate the performance of the PIP 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 results advance the technical specifications and regulations that service companies, regulators, and utilities can use for PIP repairs.

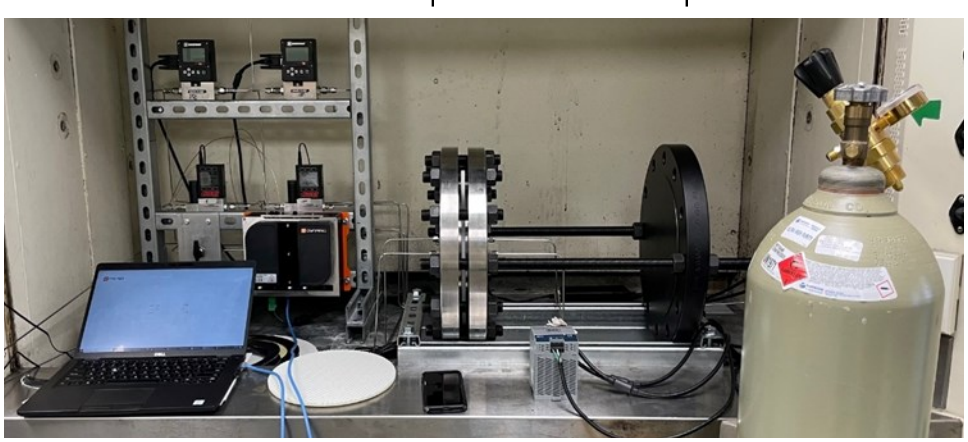
Deliverables

The deliverables for this program are:

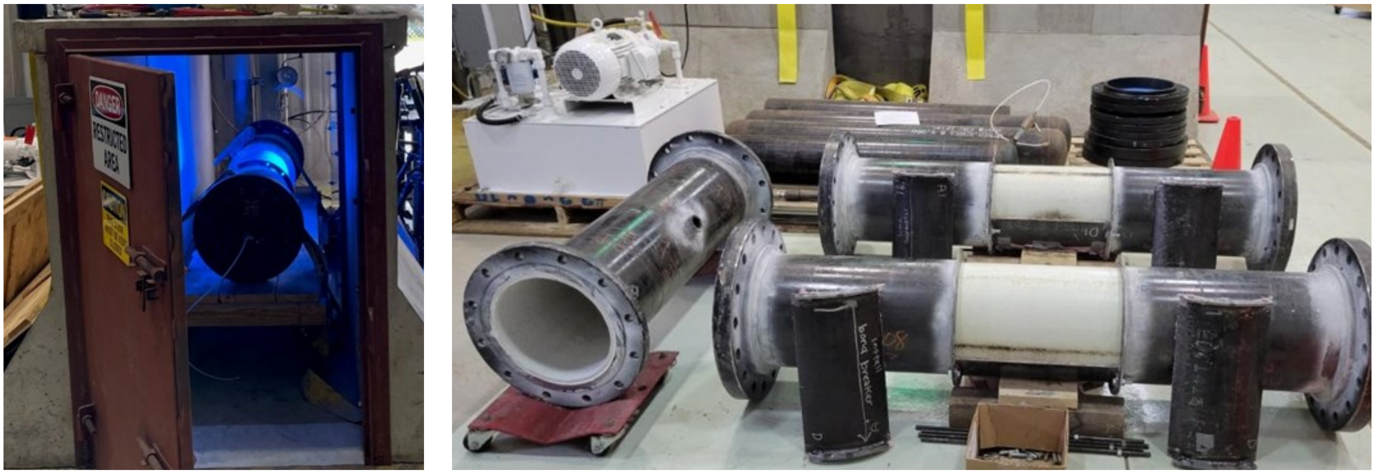
- A comprehensive technical literature review and identification of failure modes and performance criteria for PIP systems
- Analytical models for the performance of the composite materials incorporated in the PIP systems
- External and internal loading tests which address possible failure modes resulting from cyclic traffic loads, deflections, transverse ovalization, axial and bending deformation, bonding/de-bonding at the coating/liner/pipe interface, internal pressure, and puncture

Benefits

Few gas distribution system operators have Gas utilities have hesitated to implement new repair technologies due to the lack of supporting regulations, established best practices, and uniform testing and qualification procedures. This research effort will not only identify systems appropriate for use in the gas industry, but also establish acceptance procedures, as well as the testing facilities and numerical capabilities for future products.



Gas Permeation Test Cell with Repair Samples



Preparation of the Repaired Pipe Sample for Internal Pressure Tests

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 started with the characterization of failure modes and establishment of performance criteria for pipe replacement technologies. The team developed modeling and test methods based on FMs to analyze and simulate the PIP design life.

Project tasks included modifying and building new testing equipment to accommodate the testing plan and configurations of the selected repair systems. The testing plan included establishing the testing protocol and coordinating the testing schedule, number of test samples, and related installation and operational parameters.

The full-scale tests were performed on 12-inch-diameter host pipe segments with simulated damages and 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 cast iron 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 composite materials and depositions methods, requiring a new methodology for assessment and acceptance by the gas industry.

Results/Status

Project activities included performing internal pressure tests, evaluation of the service connection integrity, material gas permeability, and bending tests under cyclic loadings. These tests were performed at the GTI Energy and University of Colorado Boulder testing labs. A view of the GTI Energy tests of internal pressures and permeability are shown in figures 1 and 2, respectively. These tests were based on and modified from industry standards such as ASME PCC2 Article 4.1 on Composite Repair Systems for Pipelines, API Article 15S on Reinforced Plastic line pipes, ISO 24817 on Composite Repair Pipework, and several ASTM testing procedures.

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Operations Technology Development

Evaluation of Micro-thermal Gas Metering

To evaluate the accuracy and overall performance of micro-thermal gas metering modules while measuring hydrogen-blended natural gas and biomethane gas volumes.

Project Description

Gas utilities are increasingly interested in researching the use of hydrogen blended natural gas and biomethane and determining a reliable way to continuously measure the gas volume from hydrogen-blended natural gas and biomethane gas.

The research team is looking at a microthermal gas meter module, consisting of a MEMS-based (Micro-Electro-Mechanical Systems) calorimetric microsensor, which measures the flow of natural gas using the thermal measurement principle. The sensor element is located on a membrane and consists of a micro-heater and upstream and downstream temperature sensors (see Figure 1). The temperature distribution characteristics during gas flow are used to determine the gas velocity and the gas volume. It is integrated with signal conditioning electronics, including memory for calibration data.

Deliverables

The deliverables for this project include testing and performance results of micro thermal gas meters and a final report to OTD members.

Benefits

With the proposed inclusion of hydrogen blended natural gas and biomethane into gas industry piping systems, there are concerns about the impact of diversification of gas quality on gas metering.

Gas operators and regulators are concerned that the long-term operation of existing diaphragm type gas meters may be compromised as a result of hydrogen -blended gas and biomethane. A technology that can accurately measure varying gas compositions has potential benefit to operators seeking to transport cleaner, low carbon fuels.

Figure 1. Sensirion microthermal gas meter module

Technical Concept & Approach

The GTI Energy research team is sourcing evaluation kits from a company that manufactures microthermal gas modules and has expertise in developing MEMS-based sensors. The company has tested microthermal modules with hydrogen-blended natural gas, and the sensors have been currently tested up to 23% hydrogen by volume, with the capability to handle 100% hydrogen with necessary calibration adjustments.

The scope of this project focuses on evaluating microthermal gas metering technology. This includes a setup testing rig and performing accuracy testing of the evaluation kits and their associated meters using a sonic nozzle, air, hydrogen blended methane gas and biomethane as test gases. The testing will be benchmarked against industry references and standards that outline requirements for meters for use with natural gas. These include ANSI B109.1, DIN EN 14236, and OIML R137. Testing progress, results, and analysis will be summarized in quarterly reports and detailed comprehensively in the project final report.

Results

The team identified TUV SUD, a United Kingdom-based national engineering laboratory, to conduct the hydrogen testing portion of the project scope. The team interfaced extensively with TUV SUD throughout 2023 to resolve technical challenges and finalize the testing scope.

Status

Finalization of the subcontracting agreement for TUV SUD to perform the hydrogen portion of the project scope continues. Testing has been defined to include three (3) replicates per Meter ID, with hydrogen concentrations of 0% and 20%, and flow rates of 0.71 and 5.66 Sm^3/hr. Planning for the meter set Metrology and Special Metrology testing at GTI Energy's campus is in-progress. Testing is scheduled to begin in 2024 Q1 and a final report will be completed byQ4.

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OTD Operations Technology Development

Tracking/Reporting Aggregated Methane Emission Reductions

The objective of this project is to partner with Applied Energy Group (AEG) to implement a software program for a utility company that can quantify and report methane emission reductions as a result of infrastructure improvements, standard operating procedure updates, and renewable gas or hydrogen injection.

Project Description

As of December 27, 2021, pipeline operators are required to comply with section 114 of the Protecting Our Infrastructure of Pipeline and Enhancing Safety (PIPES) Act of 2020 that requires inspection and maintenance plans to identify procedures to prevent and mitigate both vented (intentional) and fugitive (unintentional) pipeline emissions. The U.S. Environmental Protection Agency (EPA) requires operators to report emissions of methane from various sources annually if the methane emissions exceed a certain threshold.

Reducing methane emissions is a focus for gas utilities, state legislative bodies, the environmental community, and the US Pipeline and Hazardous Materials Safety Administration (PHMSA) regulations. Currently there are questions as to how to best track emission reduction efforts and there is no standardized tracking system of what and how emission reductions are recorded. Quantifying, tracking, and reporting the methane emissions reductions gas utilities have successfully implemented is crucial to achieving the zero carbon goals many are adopting.

Natural gas has historically been vented to the atmosphere during some pipeline projects, however newer equipment and procedures have been introduced to prevent venting. AEG's software will be modified and demonstrated to OTD members a means for tracking and recording these types of methane reduction efforts and methane emission savings.

Deliverables

The deliverables are a final report summarizing all literature reviews, product screening and analysis done on H2 ready equipment, and summaries of conversations with suppliers.

Benefits

Pure hydrogen networks could represent one of the solutions to decarbonize the gas grid. Several technical challenges are identified to secure hydrogen distribution via gas grid networks such as material and equipment compatibility with pure hydrogen. Through this project, the project team will focus on network equipment & fittings.

Technical Concept & Approach

Because Applied Energy Group's Vision Demand Side Management (DSM) software platform performs similar tracking and reporting for utility energy efficiency and demand response programs, it will be used as part of this project to incorporate new gas-industry standards, processes and procedures specific to the methane emissions reduction measures. The AEG software is currently being used by several OTD member utilities and this project will demonstrate how they could benefit from this project. The software will be implemented at a gas utility and demonstrations will be held for OTD members.

Results/Status

The project was officially kicked off in Q4, 2022. AEG software delivery resources engaged the utility company and implemented approved calculation updates to add the carbon and methane emissions reduction equivalents. The new carbon and methane metrics are embedded at the “measure level” for each program and are in addition to historic calculations that were derived from kilowatt-hours savings accordingly. In addition, the calculations have been configured to “back populate” data for programs and measures for historic reporting back through 2021. The “back population” of data will allow the gas utility company to report previous years emissions reductions for these programs.

In 2022 a survey of OTD members was conducted to identify which undocumented emissions reductions (ie. gas capture equipment, vent limiting regulators, and smart metering technologies) to prioritize and calculate emission reductions. The survey identified gas capture and recompression as a primary focus. Engineering resources have been applied to draft and implement methane and carbon emissions reductions and tracking calculations for the area of focus.

Coordinating discussions with recompression equipment manufacturers was performed to ensure gas capture reporting can be standardized across these multiple manufacturers. AEG completed these measure characterizations in Q3 of 2023. The Vision System was updated accordingly for these programs with a focus on reporting methane and carbon reduction impacts. Next steps include working with the utility to define “dashboards” which will include metrics such as total annual energy savings by program and sector, total lifetime energy savings, cumulative persisting lifetime energy savings, lifetime greenhouse gas (GHG) emissions reductions, GHG equivalencies, and other metrics of interest to the team.

The draft report, OTD software demonstrations, and the final report were completed during Q2, 2024.

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Alternative-Steel and Composites for Pipelines Systems - PHMSA Cofunding

The project provides a framework and requirements for the installation, inspection, and integrity management of alternative-steel and composite systems in natural pipelines.

Project Description

Various types of existing alternative-steel and composite pipes are installed in open cuts or inserted in host pipes for trenchless rehabilitation of high-pressure oil and natural gas pipelines. These composite pipes mainly consist of two or more dissimilar layers of materials, with one or more of the layers being the load-carrying component, while the other layers provide low permeability barriers and mechanical protection. The load-carrying component mainly consists of high-strength fibers, steel-reinforced plastic, or fiber-reinforced plastic.

The resistance of these composites to chemicals and corrosion, with their high strength, light weight, and flexibility make them good candidates in trenchless rehabilitation. Most of these installations are under the Pipeline and Hazardous Materials Safety Administration's (PHMSA) special permit requirements. Their usage requires assessment of their performance and integrity against external loads and other outside threats, like the requirements under 49 CFR Part 192 for natural gas pipeline systems.

The goal of this project is to identify and address the gaps in implementing existing qualification processes of composite pipes. It maps the requirements under the CFR code to provide a standard format for the special permits issued under 49 CFR 190.341.

The main requirements for the approval of these systems pertain to material specifications, design, installation qualification, and quality control. Utilities face several challenges in issuing special permits for using this material, including:

- Most of the material specifications are based on the product/vendor-specific data,
- The need for specifications to address the variable construction issues in the field, quality control, and inspection processes during installation,
- Development of non-destructive evaluation and in-service inspection procedures,
- Determine susceptibility to external threats and evaluate integrity management procedures,
- Long-term performance of the material, potential failure modes, and repair.

Deliverables

This project is co-funded by an approved PHMSA project. The following scope of work presents the tasks under the PHMSA-funded Project:

- Evaluate Material Properties
- Design for Maximum Allowable Operating Pressure (MAOP)
- Assessment of Construction Damage and Quality Assurance
- Assessment of Corrosion/Erosion Damage.

The OTD co-funding work is supporting the following tasks:

- Assessment of Integrity Threats
- Degradation of Composite Material
- Field Inspection and Monitoring for IM
- Review of Code Requirements.

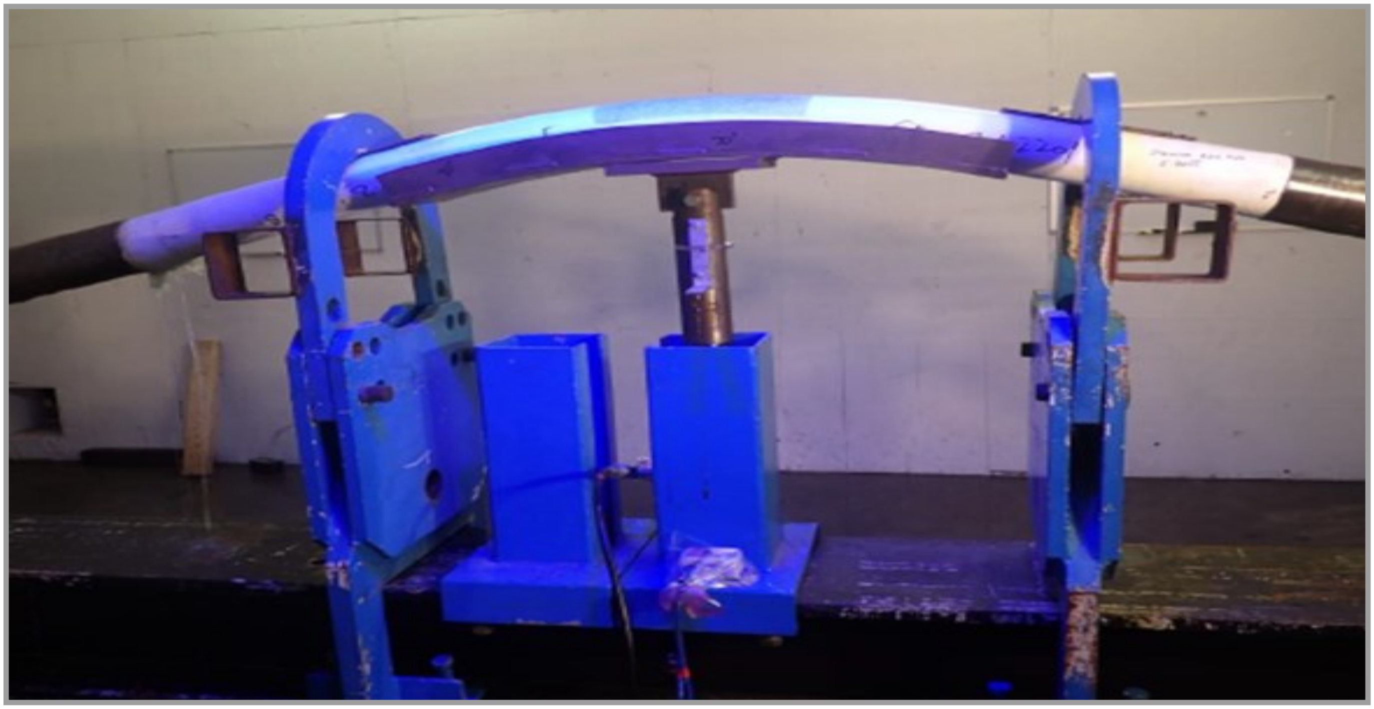

Figure 1. Pressurized Composite Pipe Sample Under Bending Loading Test

Benefits

The use of alternative-steel and composite systems in natural gas lines provide a safe alternative in applications requiring resistance to corrosion where access for internal and external integrity management inspection is challenging, such as in highway and river crossings.

Technical Concept & Approach

The project is investigating the following:

Risk-based threats identified in API 1160 code are being reviewed to identify how alternate materials could affect the methods used to evaluate these threats compared to steel pipe.

Evaluating the degradation of the composite material properties due to varying service conditions such as pipe material, pressure, elevated temperature, product chemical components, and environment.

Inspecting and assessing damage and defects of non-steel pipes and connections and the applicability of existing integrity methods, such as direct assessment and pressure tests, to evaluate threats.

Results

An evaluation of the required material strength properties and testing procedures is completed. This included performing stepped loading tests to determine long-term performance of the composite.

A testing program to evaluate the effect of construction and external loading, resulting in bending stresses, was performed.

As a part of the integrity management task, a review was performed on the relevant effect of corrosion of alternative-steel pipes and erosion in non-steel composite pipe materials under various operating conditions and environments.

Status

The OTD-funded project is in progress with expected completion on December 31, 2024. The on-going work of the project addresses impact to integrity, degradation, and requirements for installation permits.

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Pressure Monitoring and Alert Device for the Replacement of Token Reliefs

Researchers will Identify or develop a low-cost pressure monitor in order to provide continuous pressure monitoring around pressure relief valves. This will provide operators with potential anomalies to further investigate, which provides both safety and environmental benefits.

Project Description

The goal of this project is to identify and potentially develop a low-cost pressure monitoring device that can be installed in conjunction with relief valves (token or full relief) or monitor regulator.

Pneumatic pressure relief valves are mechanical devices that release gas to the atmosphere when a pressure set point is exceeded. Full reliefs are typically installed in conjunction with district regulator stations and/or large commercial and industrial meter sets to protect downstream piping from over pressurization conditions. Some operators use token reliefs to provide audible warnings when pressure downstream of a regulator exceeds a pressure setpoint.

Relief Valve Assembly

Continuous monitoring allows operators to potentially be more proactive in reviewing and as needed adjusting pressures before the pressure relief valve set points are reached.

Deliverables

Deliverables for this project will include an analysis of the current usage of pressure relief valves, an updated survey of pressure monitor needs, prototypes of a LoRaWAN enabled pressure monitor, a review of commercially available pressure monitors, test results for prototypes and commercial devices, and reporting and data products including a close-out webinar.

Benefits

A monitoring device that could quickly inform operators of pressure anomalies would have multiple benefits. By reviewing and addressing potential anomalies quickly can eliminate potential safety event and protects the public and maintains reliability of the pipeline network. Additionally, preventing the need for the relief valve to operate directly reduces methane emissions. Continuous pressure monitoring can provide utilities time to act before the relief operates. Continuous monitoring can also prevent under pressure events.

Technical Concept & Approach

Survey Utility Requirements

As part of an earlier project, an AGA SOS questionnaire was developed to capture requirements for remote pressure monitor devices. This will be refreshed to include questions specific to pressure relief valves and update some questions to reflect changes in wireless and AMI technology since the original survey of 2014. It will include questions regarding the cost sensitivity of the use cases.

Build Out LoRaWAN Devices

OTD developed LoRaWAN-enabled pressure monitor hardware during project 8.17.a "Internet of Things (IoT) Technology for Gas Operations Monitoring". Several prototype LoRaWAN pressure sensors were built and successfully tested. A commercial source of LoRaWAN enabled pressure sensors will be sought. Alternatively, GTI Energy can duplicate more of the earlier prototypes for testing.

Review/Procure Commercial Devices

Survey the market for commercial off-the-shelf (COTS) wireless pressure monitors, guided by the survey results. Manufacturers will be contacted for detailed information on their systems. Review the findings with the sponsors to determine pressure monitor systems of particular interest. Obtain selected systems for direct evaluation.

Pressure Monitor Testing

Test the commercial pressure monitors of interest and the LoRaWAN system. Develop a testing program and share it with the project sponsors. Include tests for COTS relief valves alongside the pressure monitors. Develop a dashboard for sponsors.

Results/Status

The project team updated the AGA SOS questionnaire to address technology changes that have occurred since the original version was produced. The updated questionnaire was ishared with project sponsors to review and comment.

The project team worked on the agreement with a manufacturer, to produce LoRaWAN compatible pressure sensors. A set of sensor specifications were finalized. GTI Energy is now working with the manufacturer to obtain production prototypes of LoRaWAN pressure sensors that are suitable for Class 1 Division 2 areas. The manufacturer already produces commercial C1-D2 pressure sensors and was able to adapt these to the LoRaWAN radio system. GTI Energy is currently procuring six sample devices from the manufacturer, and the sample devices are expected to arrive in 2024.

The project team surveyed commercial-off-the-shelf (COTS) market for wireless (non-LoRaWAN) pressure monitors. Several solutions were identified and manufacturers were contacted to address questions and obtain more detailed information. One manufacturer was selected to be evaluated with in-house testing. The device obtained uses LTE cellular communication and is suitable for Class 1 Division 2 locations. GTI Energy has done some bench testing of this sensor and plans to put it in an outdoor location for further testing.

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5 Gas Distribution System Overview - Virtual Reality (VR) Environments

Develop a gas distribution systems overview training module using virtual reality (VR) training technology. These virtual environments allow trainees to explore and experience photo-realistic environments and gas distribution assets without going into the field.

Project Description

As the utility industry prepares for 40-50 percent of its workforce to retire over the next five years, local distribution companies (LDCs) 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 lab under ideal conditions.

Companies need to bridge this experience gap of trainers and are looking to leverage virtual reality (VR) training to address both gaps. The training module proposed in this project will contain a training module that will mimic a gas distribution system and will apply existing code requirements to the virtual gas system. The module consists of two different environments; a city and residential, complete with different gas distribution system components and their material and installation information.,. These components will consist of Polyethylene (PE), steel, and cast-iron piping materials/mains and service piping, branch services, mainline and service valves, excavations with shoring, job site safety, meters and regulators, inside and outside services, underground vaults, pipeline markers, etc.

Deliverables

The deliverables for this project include developing a gas distribution systems overview module in two

Figure 1. Inside meter inspection environment

Figure 2. Stand-by activities environment

virtual environments, a residential neighborhood, and a city landscape. In addition, these modules will have three different modes: A virtual instructor-guided mode, a training module, and an assessment mode. In addition, these modules have multi-user, grading and reporting capabilities. Modules are built on a platform that allows customization of information as required.

Benefits

Incorporating VR into LDC training programs may increase learner engagement and retention rates which can improve employee performance. The VR training also simulates realistic, dangerous, or risky situations within controlled environments. This allows personnel to train for responding to emergencies.

VR training may also aid in training large numbers of personnel over various locations and provides visualization of complex concepts and theories. Lastly, VR training helps ensure consistency of training, reporting, and tracking capabilities.

Technical Concept & Approach

Development and use of photo-realistic, interactive, and immersive VR training modules offers LDCs several operational advantages. For example, the use of VR modules may improve learner retention, the consistency of training delivered, allow the training to be conducted on demand by operations, increase the number of real-life training scenarios available for trainees to experience, reduce the risk of injury, while reducing the cost of instructor labor and materials for preparing traditional classroom and lab 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.

The repeatability and immersion into the environment will allow LDCs to train more personnel for a variety of scenarios they may encounter in the field. The tracking and reporting capabilities of VR modules monitor a trainee’s progress and performance and allow the training instructors to assess a trainee’s readiness for the field.

Results

Oberon’s development of the VR training experience started in 2023, and the VR experience was published to the platform in June 2023. The published module is currently being tested using VR headset devices and on standard laptop computers. The GTI Energy project team tested both Gas Distribution System Overview environment, the residential and city, and provided feedback to Oberon Technologies for making updates by the end of 2023.

Status

The final report was completed in March 2024.

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Project No. 5.22.i

Gas Engineer Training Program Development

Development of a structured gas engineer training program for new engineers entering the industry on an advanced learning management system (LMS) system. Use of these modern learning methods will better meet the needs of new engineers entering the workforce.

Project Description

This training program consists of blended learning lessons that will include eLearning, micro learnings, interactive videos, gamification, quizzes and assessments, learner paths, social communities to discuss training topics, etc. Use of these modern learning methods will better meet the needs of new engineers entering the workforce.

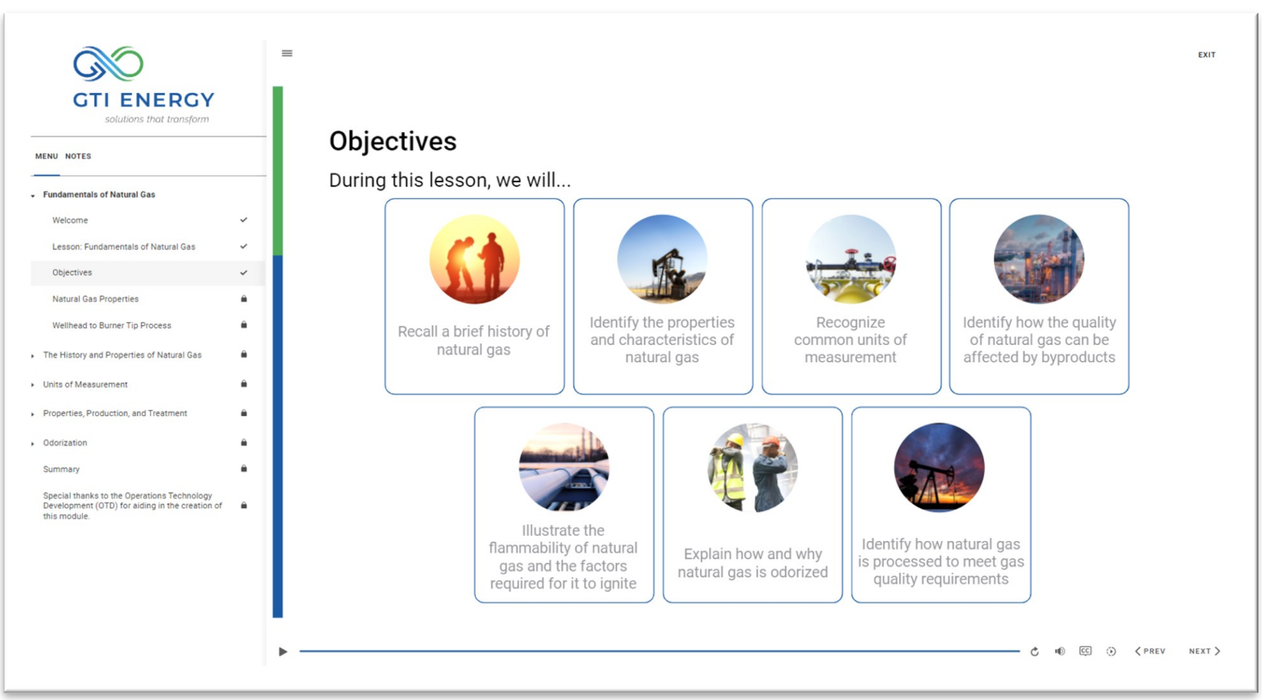
Deliverables

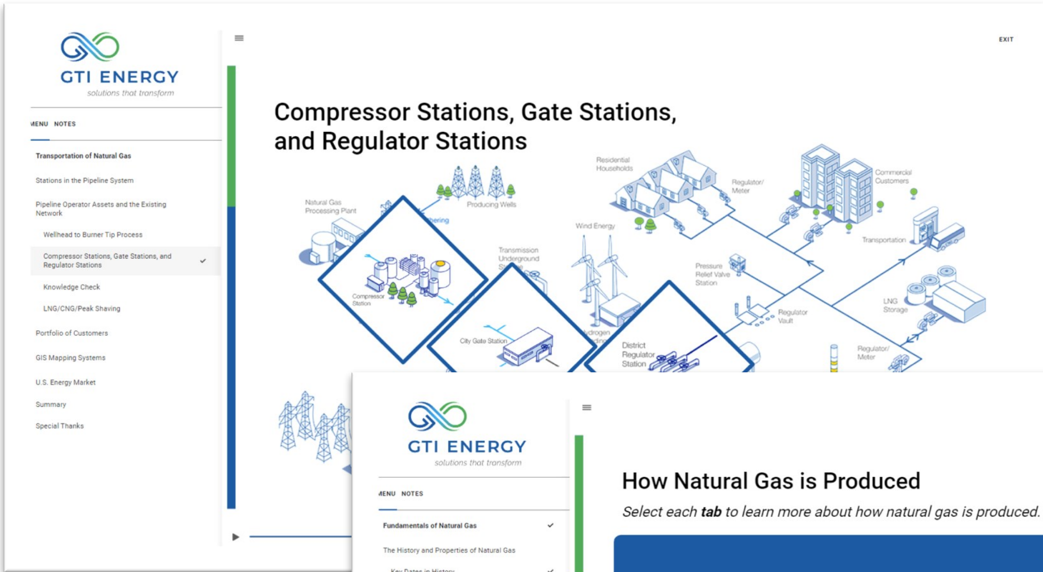
The deliverables for this project include developing seven gas engineering training modules using an advanced LMS platform with an estimated 35 lessons consisting of 4-6 exercises within each lesson for a total of 210 lessons. In addition, a final report will be prepared detailing each module, lesson, exercise, and type of advanced training technology used for each.

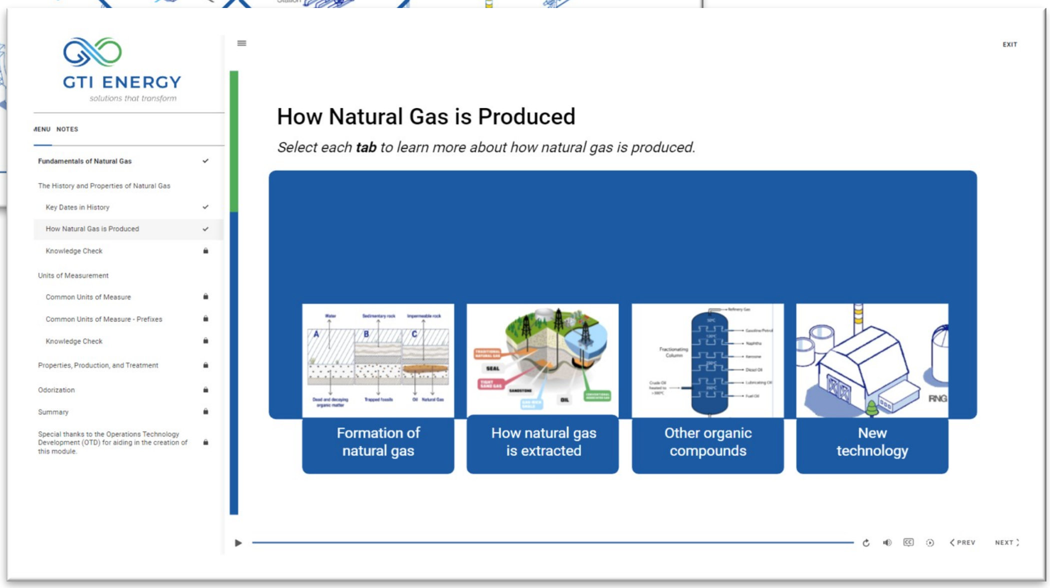
Benefits

Development of a structured gas engineering training program, using modern training technologies and methods, will lead to a more engaging and interactive training experience for new gas engineers. As a result of meeting the needs of modern learners, training retention will increase and lead to a more competent engineering workforce earlier in their careers.

Also, the use of modern training methods will allow for hours of training content to be delivered as more manageable training exercises with an anticipated duration between 5 and 15 minutes for each exercise. Modern training technologies will allow for the learner to stay actively engaged with the training content as the modules are shorter. The modules are designed to provide engineers with the necessary training over time, and designed with the intention to minimally impact their daily work assignments.







Lastly, the use of an advanced LMS will allow for delivery of training content anywhere and anytime on mobile devices, tablets, or an office computer.

Technical Concept & Approach

As the utility industry prepares for 40-50% of its workforce to retire over the next 5 years, LDC's 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 job shadowing in the office, computer-based training, classroom discussion, and presentations.

GTI Energy has over 66 hours of existing gas engineering training content that will be leveraged as part of this project. GTI Energy training personnel, in collaboration with a national engineering firm who has expertise in gas engineering practices, will also be providing input and guidance on content for each of the lessons. GTI Energy will also leverage its expertise in gas engineering practices, advanced training technologies, instructional design, LMS platform management, and overall utility training program development and deployment .

Results and Status

Storyboard material development was completed in Q3 and.eLearning content development is underway. Also, lessons for Module 1 were reviewed by OTD Subject Matter Experts and Module 2 development is underway.

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OTD Operations Technology Development

Design and Placement of Compact Service Regulators

The objective of this project is to test existing "vent limited" service regulators to provide evidence that they offer a reduced area of influence and offer more installation options as compared to traditional internal relief valve (IVR) service regulators.

Project Description

This project involves working with local gas distribution companies, OTD Technical Advisory Panel (TAP) members, regulator manufacturers, and industry subject matter experts to identify service regulators on the market with "vent limiting" capabilities. The team will review existing regulator installation procedure documentation and clearance distances to prepare a baseline for testing purposes, perform comparative testing of "vent limited" regulators to traditional internal relief valve regulators pertaining to the amount of gas vented under normal and varying operating conditions, such as a torn diaphragm and lever disconnect. The team will formulate recommendations and disseminate the findings in an industry workshop to provide scientific support and procedures for inside, outside and confined space clearances.

Phase 2 of the goal was to use existing data from 5.22.j and modify the gas coefficient to observe changes in venting from gas service regulators when the fluid composition includes not only methane but also a blend of methane and hydrogen.

Phase 3 will test the Pietro Fiorentini Cirval Gas Service Regulator. The team will perform the testing on a sample of six Cirval gas service regulators using the test plan identified in the proposal.

Phase 4 will evaluate the newly released Pietro Fiorentini gas service regulator versions: NR (No Relief), Calibrated Relief, and Token Relief using the same methods used in Phase 1.

Deliverables

The final report for this project will summarize commercially available "vent limiting" regulators, review regulator installation procedures focused on venting requirements, outline recommendations for developing a testing plan for the comparative regulator testing, , and compare testing results for IRV and vent limiting regulators. This project is cost shared by US DOT-PHMSA and the results of this project will be presented in a technology workshop/ webinar.

Benefits

Natural gas utilities prefer to install new meter set assemblies (MSAs) outdoors; however, finding appropriate locations with sufficient clearances from building openings (doors and windows), vents, and potential ignition sources can create challenges. In addition, gas utilities are relocating existing inside MSAs (meters and/or regulators) outdoors. This is not always feasible due to space constraints (especially in congested urban environments), local building codes restricting their outdoor placement, landmark and historic district restrictions, and security or sensitive building designations. This project aims to provide testing to confirm if newer "vent limited" gas service regulators will allow for smaller clearances.

Technical Concept & Approach

The project will measure the level of natural gas produced from "vent-limiting" service regulators as compared to traditional IRV service regulators to determine safe clearance distance requirements. Experimental testing will determine if "vent-limiting" service regulators offer more options for outside installation by having a smaller footprint that includes the ability to install at reduced clearance

Above: Examples of Gas Service “Vent Limited” Regulators

Examples of Gas Service Traditional IRV Regulators

distances as compared to traditional IRV service regulators. The safe distance allowances will be determined through testing the amount of gas vented during various regulator operating flow conditions and failure modes, including diaphragm ruptures.

Results/Status

In 2022, a project technical advisory committee was established which reviewed commercially available vent limiting regulators, reviewed existing clearance requirements, and developed a testing plan of gas service regulators. Three manufacturers that produce “vent limiting” style gas service regulators were selected for testing.

A draft final report for Phase 1 was delivered to PHMSA at the end of Q4, 2023. The draft final report was reviewed with the industry during Q1, 2024 and the project will be presented at the AGA Spring Operations Conference during Q2, 2024.

For Phase 2, The findings indicate that increasing the hydrogen content in the blend results in decreased venting. It is important to note that the quantity of gas flowing through the system during the testing remained the same as the amount which was recorded in the previous project (5.22.j).

For Phase 3, the scripts for the gas service regulators are currently being written to facilitate the corresponding testing, including the Relief Test and the Locked-Up Test. The second phase of the project will commence after the completion of all testing in the EFV (B109) rig.

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Evaluate Hydrogen Blend Measuring Devices

To assess, evaluate, and compare the performance and effectiveness of various discrete non-Gas Chromatography (GC) hydrogen measuring devices for Hydrogen/Natural Gas-blended gas distribution operations.

Project Description:

Local distribution companies (LDCs) who are conducting hydrogen blending projects need to measure and monitor hydrogen blend percentage. A review of newly commercialized hydrogen measuring devices may be a lower cost alternative to existing gas chromatography GC technologies.

Some research has already taken place in which these types of devices have been tested in low-pressure, low-flow applications in appliance fuel lines. The aim is to not duplicate that research; rather add to it and verify that these types of devices can perform adequately and are suitable for use in a higher-pressure distribution pipeline application.

Deliverables

A final report will be drafted that provides the results of the evaluation performed and recommendations for the GC alternative devices.

Benefits

As more LDCs explore blending hydrogen into their pipelines, a lower cost hydrogen measuring device that can connect directly to the pipeline and remotely measure, and analyze hydrogen content, and operate without significant manual user interaction while providing accurate, dependable, and repeatable results can add great value to LDCs and their customer base.

Technical Concept & Approach

As part of industry-wide decarbonization efforts, LDCs are undertaking hydrogen blending projects to blend hydrogen gas into their natural gas distribution pipelines. An important parameter for them to measure and monitor is the amount of hydrogen being blended into the natural gas pipeline. The systems that meter and blend hydrogen into the pipeline can be set and controlled to deliver a chosen percentage of hydrogen (much like odorization equipment), but it is essential for LDCs to independently monitor that percentage separately from the blending unit, downstream of the injection point.

The project team will research the market to identify devices that detect and measure hydrogen blends in an inline-mounted pipeline application operating at distribution pressures. The project team will conduct testing to evaluate the performance of various measuring devices and produce a report on their ability to deliver comparable results to existing GC technology.

This project consists of the following tasks:

- Technology Review & Device Procurement - researching the market of available devices and acquiring the appropriate devices.
- Lab Testing - This task will include lab testing of the acquired devices. Testing in GTI Energy's Pipe Farm will be included if possible (GTI Energy's Pipe Farm enhancements, including hydrogen blending, is a separate project with a separate timeline).

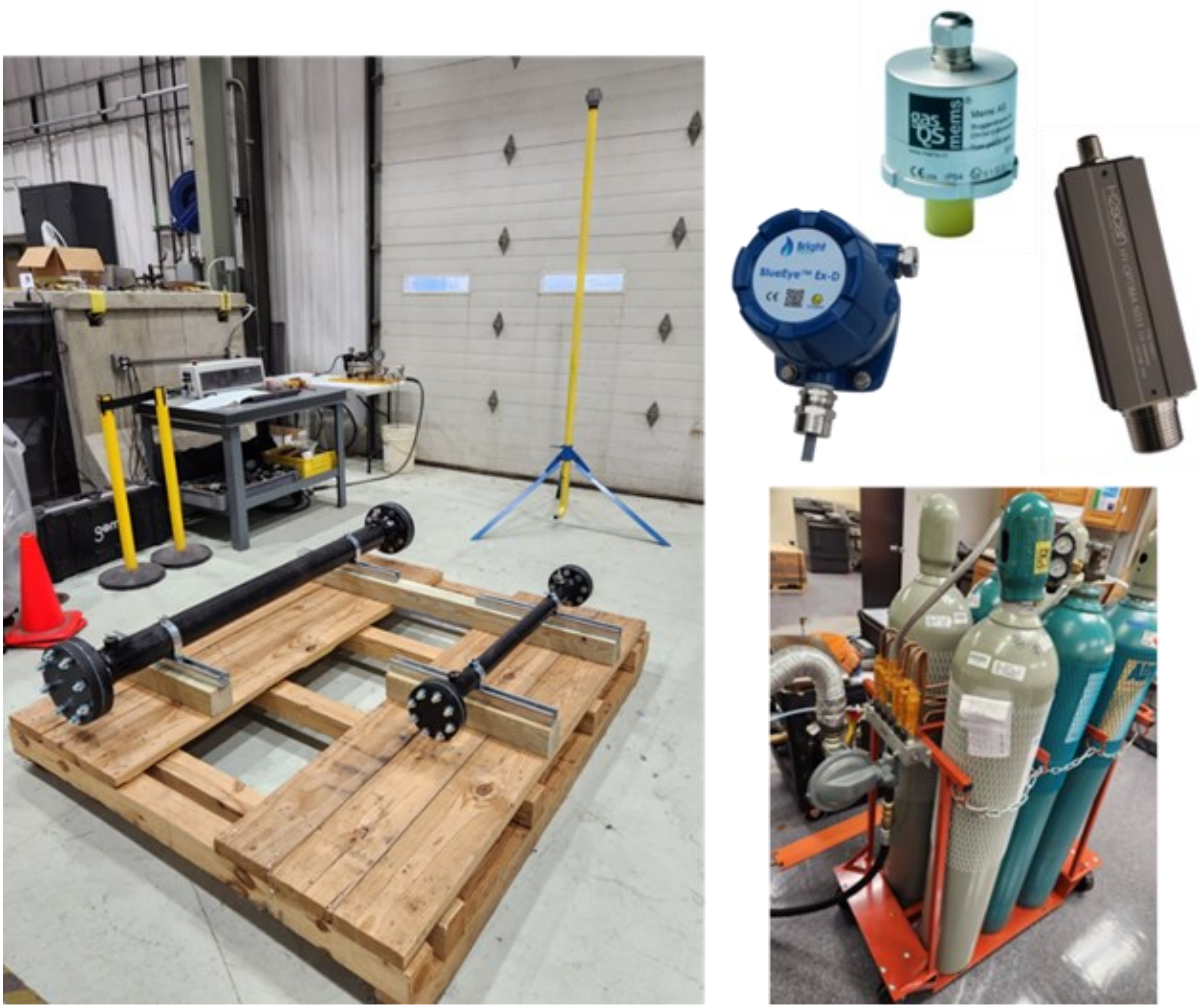

Figure 1 - Test Rig Pipes with vent flare stack, example H2 Sensors, and example gas supply cylinders

- Reporting - The work in this task includes writing quarterly reports and a final report. The performance of the hydrogen measuring devices will be detailed in the final report.

Results and Status

In Q3, 2023, the Project Team began assembling the testing rig and it met with multiple hydrogen sensor vendors to discuss requirements, pricing and availability.

In Q4, progress was made fabricating the testing rig with 2″ and 4″ diameter steel test pipes. In 2024, GTI Energy will continue work on acquiring sensing devices and building and assembling the remaining parts of the test rig. The project is expected to be completed by Q4 2024.

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Remotely Deployed Double Balloon Stopper - Design Refinement

To further develop and refine prototypes of two remotely deployed balloon stoppers from a single location to seal both sides of a leaking pipe in two specific applications.

Project Description

The GTI Energy Team is incorporating knowledge gained from previous projects (SMP 22702 & OTD 2.5.a) to develop a remotely deployed double balloon stopper prototype which can seal a leaking gas main for each of the following two scenarios:

- Small Diameter (2″ IPS - 4″ IPS) – high pressure (60 psig) systems (with a built-in bypass)
- Large Diameter (16″ IPS -24″ IPS) – low pressure (<2psi) systems (without a Bypass)

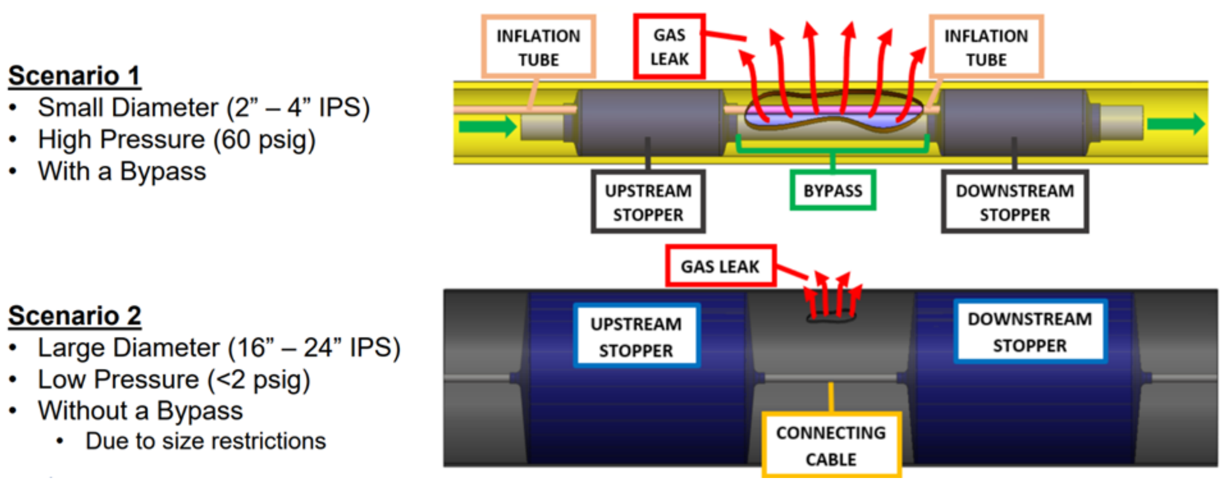
Deliverables

The deliverables for this project include: a fully tested, final prototype double balloon stopper, for small diameter (2″ IPS - 4″ IPS) – High Pressure (60 psig) systems (with a bypass); a fully tested final prototype double balloon stopper for large diameter (16″ IPS - 24″ IPS) – Low Pressure (<2psig) systems (without a bypass); and a final report.

Benefits

Developing a method for remotely sealing a leaking pipe caused by third-party damage allows for first responders to stay safe by not having to perform emergency operations near the leaking gas.

Creating a method for deploying dual balloon stoppers that are needed for a double block and bleed from a single location reduces the amount of time it takes to deploy the stoppers since only one location needs to be excavated and prepped. This may reduce the costs for the local distribution company (LDC) for having to access and stop the gas leak. Additionally, by deploying this tool from a remote location, this will also allow the LDC to seal off a gas leak in an inaccessible location where a traditional double block and bleed is not possible. Lastly, developing a method for providing a bypass through a double balloon stopper allows the LDC to continue supplying service downstream of the gas leak while the pipe is being repaired.



The two prototypes that the research team is developing and testing

Technical Concept & Approach

The natural gas industry has multiple ways of stopping off the flow of gas to create a repair by deploying balloon stoppers locally at a single location. GTI Energy has performed previous project work regarding deploying two connected balloon stoppers in a small diameter service line (<2″ IPS) at high pressure. However, there are two critical applications where developments in this area are needed:

The first application is to further develop the double balloon stopper prototype with a bypass for small diameter (2″ IPS - 4″ IPS) – high pressure (60psi) pipeline, that was developed from SMP project 22702 Rapid Gas Shut-In, by increasing the size of the bypass. By doing so, LDCs can supply a larger volume of continued service downstream of a gas leak while the pipe is being repaired.

The second application is to develop a double balloon stopper prototype which can be used in large diameter (16″ IPS -24″ IPS) low pressure systems (<2 psig), since there are currently no prototypes on the market consisting of two connected large diameter balloon stoppers. This will allow LDCs in markets with large diameter piping to perform stop-offs remotely from one location, allowing them to be able to shut off a gas leak faster since only one excavation will be needed.

Typical access holes for small diameter pipe (8″ IPS and smaller) are 2in or smaller in diameter, which is very close to the diameter of the pipe. Therefore, a solid bypass which is a greater percentage of the small diameter pipe can enter the access hole. However, a typical access hole for large diameter pipe (16″ IPS and larger) is a 4in diameter hole for a 4″ NPT plug and does not increase for larger pipe sizes. A solid bypass that could fit through this access hole would significantly restrict the percentage of flow through the pipe. A flexible bypass could be inflated to increase in size, but it wouldn't provide the rigidity required to push two large diameter balloon stoppers a significant distance down a gas main (100ft or greater). This is why a bypass is only being developed on the 2″ – 4″ IPS system.

Results/Status

During the 4th quarter of 2022, the project team began work on the development of both double balloon stopper designs, developing a mockup of the Connected 2in Double Balloon Stopper and successfully inserted it through an Entry Fitting into a 2in pipe. The Team also successfully pushed two connected 24in balloon stoppers through a 4in launch tube into a 24in balloon stopper and inflated to fill the main at 2psi.

During the 1st quarter of 2023, the team continued to work with the bag manufacturers to develop molds to create 2in balloon stoppers with multiple thicknesses and durometers. However, the bag manufacturer was unable to create these 2in balloon stoppers during this quarter.Additionally, during this quarter the project team continued to work on making the deployment of the two connected 24in balloon stoppers through the 4in launch tube easier. Researchers found that adding a small simple stiffener between the balloon stoppers did not have any added benefits to the deployment process. In the upcoming quarter (Q2 2023), The project team will continue to evaluate additional stiffener sizes with significant curvatures inherent to the stiffener to find a suitable option for easily deploying two connected 24in balloon stoppers into a 24in steel pipe.

Throughout the remainder of 2023, the project team continued to test alternative stiffeners to assist with the deployment of the two connected 24in balloon stoppers. It was found that using the inflation line as the insertion line, a 0.5in polyurethane tube, helped get the balloon stoppers into the 24in steel.

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Hydrogen Blending Program

This project is monitoring technical, knowledge, and operational barriers to blending hydrogen (H2) in natural gas pipelines. The program is compiling and documenting current scientific and technical efforts and identifying gaps.

Project Description

The goal of the Hydrogen Blending Program is to develop and communicate an understanding of the state of hydrogen blending in current natural gas piping systems. Key topical area materials compatibility, operational procedures, and safety considerations. The introduction of hydrogen in increasing quantities poses challenges for pipeline operators, who must weigh the benefits of higher H2 concentrations into existing infrastructure against the costs and risks associated with retrofitting the pipeline system.

Hydrogen is one of a handful of low carbon solutions that will be critical for the transition to net zero by 2050. As part of a deeply decarbonized, deeply renewable energy system, low carbon hydrogen could be a versatile replacement for high-carbon fuels used today – helping to reduce emissions and providing flexible energy for power, heat and transportation.

In order to succeed in their decarbonization efforts, natural gas operators and government regulators will need to address several technical, operational, and legal barriers before the benefits can be realized from blending and transporting hydrogen into existing natural gas piping systems.

Deliverables

The deliverables of the program are a series of reports on the various research and evaluations performed as well as a guideline document summarizing the program's findings.

Benefits

This Hydrogen program creates an opportunity for gas industry stakeholders to work together to identify the research gaps and develop the necessary information to progress towards the safe and efficient use of hydrogen in our future energy systems. Testing and evaluation of system components, equipment, methods and procedures are better suited for testing in a controlled laboratory environment before operators inject hydrogen into their pipelines.

This program provides value by:

- Identifying and addressing gaps in current research investigating H2 blending in existing natural gas infrastructure.
- Gaining knowledge on how H2 can be safely and efficiently blended into current gas piping systems while maintaining pipeline and public safety.
- Bringing together industry experts to share knowledge, identify research gaps and exchange insights around H2 blended systems.
- Provide information and resources to OTD sponsors to allow them to make decisions on how to move forward with H2 blending efforts.

Technical Concept & Approach

The program scope will focus on the following 4 tasks:

Monitoring of hydrogen projects at GTI Energy - The status of OTD projects related to hydrogen will be shown on the Hydrogen Information Site landing page and sponsors are able to understand ongoing work.

Compilation of public findings from demonstration blending projects - A review of relevant completed projects that injected hydrogen into existing natural gas systems will be conducted as results become available.

Tracking manufacturers declarations assuring compatibility with hydrogen - Due to the lack of standards to test components with hydrogen, manufacturers are starting to put out declarations to assure that their components are compatible with hydrogen.

Status of standards development for hydrogen compatibility - As it was identified in OTD Project 5.21.s, Gap Identification between Hydrogen and Natural Gas Standards, there are many standards throughout the world that have been identified for revisions to accommodate the use of hydrogen. The results of these revisions can serve as steppingstones for other regions where the process is lagging or has not been initiated yet.

Results/Status

A meeting to finalize scoping was held with sponsors in August 2023 and a scope document was issued in September and posted on the secure OTD project webpage. A new section was created on the Hydrogen Information Site (created in OTD project 7.19.h Hydrogen Injection Pilot Resources). A process for hydrogen blending and instrumentation diagram (P&ID) for hydrogen blending, as well as learnings from Pilot Projects: HyDeploy, Phase 1, have been uploaded to the webpage.

This program is actively tracking the four identified scope tasks above and will be active through Q4 2024.

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NPTF Threaded Fittings and Other Alternative Joint Connections for Meter Set Joints

Researchers will test the performance of National Pipe Taper Fuel (NPTF - Dryseal) threaded fittings against traditional NPT fittings to determine the potential for reducing nuisance leaks, saving on repair costs, and minimizing methane emissions.

Project Description

Utility crews are routinely tasked with repairing leaking meter set assembly (MSA) connections that were built using general-purpose National Pipe Taper (NPT) threads. These threads are commonly used for gas applications. Sealant applied during installation can deteriorate over time and may result in future nuisance leaks.

Identifying other fittings which can further prolong the occurrence of nuisance leaks allows for crews to perform other work, reduces costly repairs, and allows operators to reduce releases into the atmosphere.

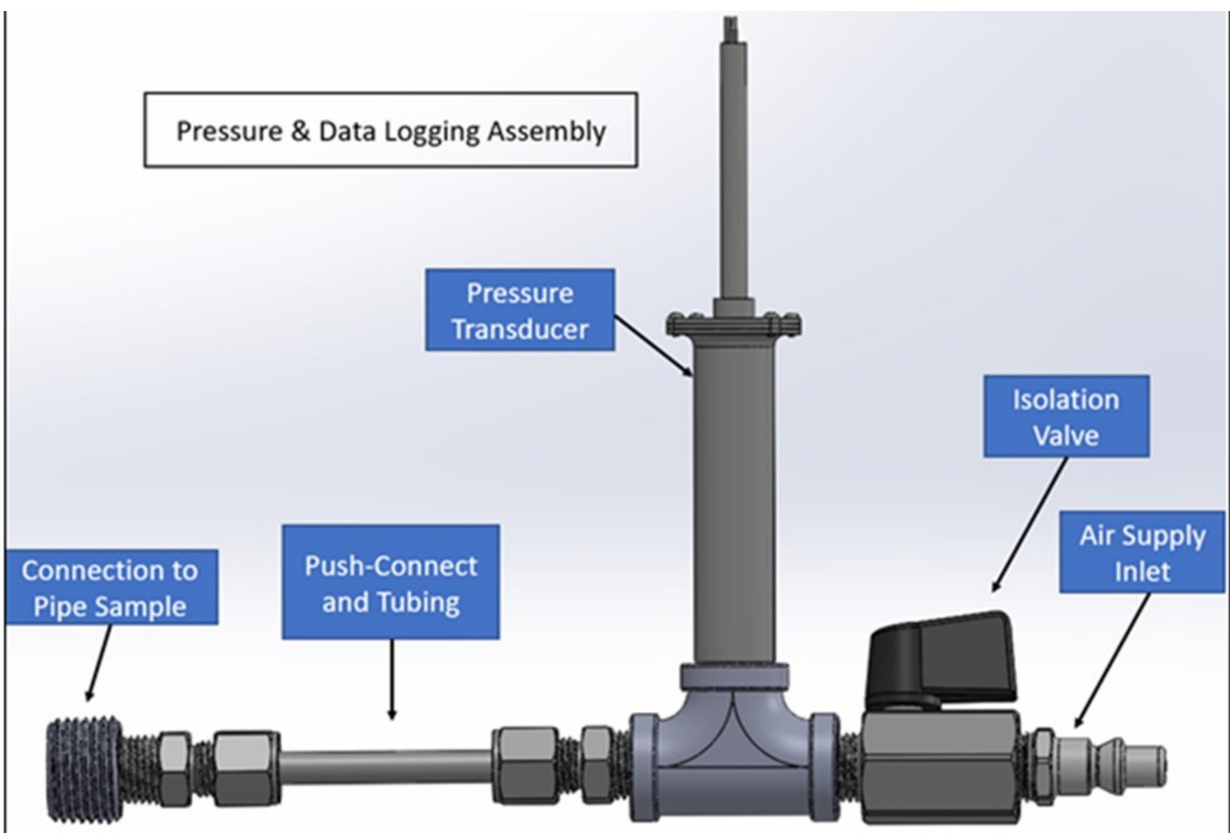
Minimizing releases continues to be a focus for gas operators and also serves as a measure to eliminate fugitive emissions. Several operators are reviewing their sources of emissions to better align with The PIPES Act of 2020, Section 114, which directs pipeline operators to update their inspection and maintenance plans.

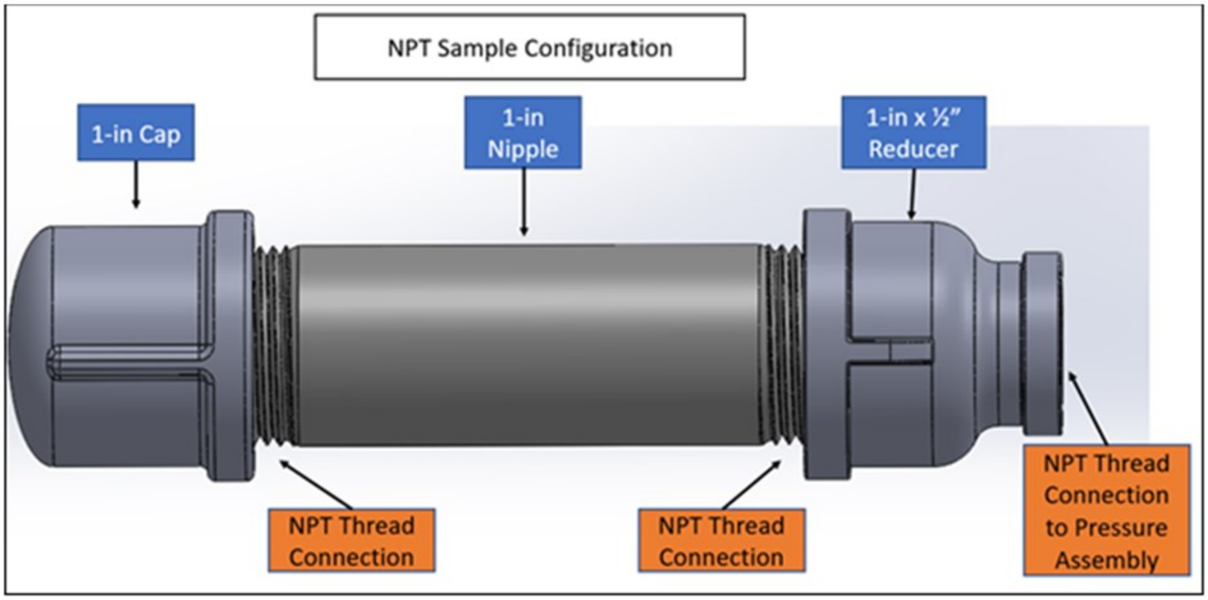
The purpose of this project is to test the performance of National Pipe Taper Fuel (NPTF - Dryseal) threaded fittings in comparison to traditional NPT threaded fittings and evaluate fitting performance.

Deliverables

The deliverables of this project will include:

A final report that summarizes all the results and compares the performances of the different thread





Test sample configuration

types. A cost analysis will also be included to compare the average cost of repairing nuisance leaks against the cost of using different thread types that may prevent these nuisance leaks from occurring.

Benefits

Utilizing threads manufactured with higher tolerances can significantly reduce the occurrence of nuisance leaks compared to general-purpose NPT threads. This reduction leads to fewer repairs and maintenance, conserving utility resources, and translating to cost savings as companies spend less on labor and materials. Fewer gas leaks also contribute to lower methane emissions. This effort supports the natural gas industry's initiatives to mitigate fugitive emissions and comply with the PIPES Act of 2020, which mandates the elimination of hazardous leaks and the minimization of natural gas releases.

Technical Concept & Approach

Identify Alternative Types of Threads

This task will identify alternative types of threads and compare the dimensional tolerances in each thread type's respective standards. The team plans to include NPTF and ANPT in this study to compare to general-purpose NPT.

Fittings Testing

The work in this task will include purchasing of the fittings and measurement of the threads. All pipe nipples and fittings used for sample construction will first be measured to ensure that they have conformant threads.

The work in this task will also involve creating test samples with fittings of each thread type that passed dimensional inspection. These samples will be pressurized and subjected to environmental testing to evaluate thread type performance in their ability to retain a leak-tight seal in different conditions.

Results/Status

After a 10-month delay due to the production of NPTF threaded fittings, the project team received the components and measured them to verify compliance with the standards. The project team has enough fittings to create three sets of 15 samples, which will be constructed, pressurized, and subjected to temperature cycling while data logging each sample's internal pressure.

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Hydrogen Detection Tape Evaluation

Project Description:

Hydrogen detection tapes enable the visual detection of hydrogen gas leaks by changing color permanently when they come into contact with hydrogen gas. This project aims to identify and evaluate different hydrogen detection tapes available in the market. It assesses their performance under various hydrogen leaks, including multiple blends, and sizes, as well as different environmental conditions.

Deliverables

This project will identify suitable products for quick and easy detection of hydrogen leaks and develop a final report that describes all product testing and evaluation results.

Benefits

Detecting hydrogen leaks using conventional handheld devices is a manual and time-consuming process. When leaks are detected, pinpointing the exact location can be tedious and costly for companies. Hydrogen detection tapes offer a solution by allowing operators to visually identify the precise leak location. These tapes can be applied around pipe connections to provide a clear visual indication of the presence of a leak, resulting in cost and time savings. Furthermore, this method serves as a valuable safety measure, especially when dealing with pipe systems containing hydrogen-blended gas.

Technical Concept & Approach

This project explores the feasibility of whether these products can help operators - detect leaking joints as they introduce hydrogen into their piping system.

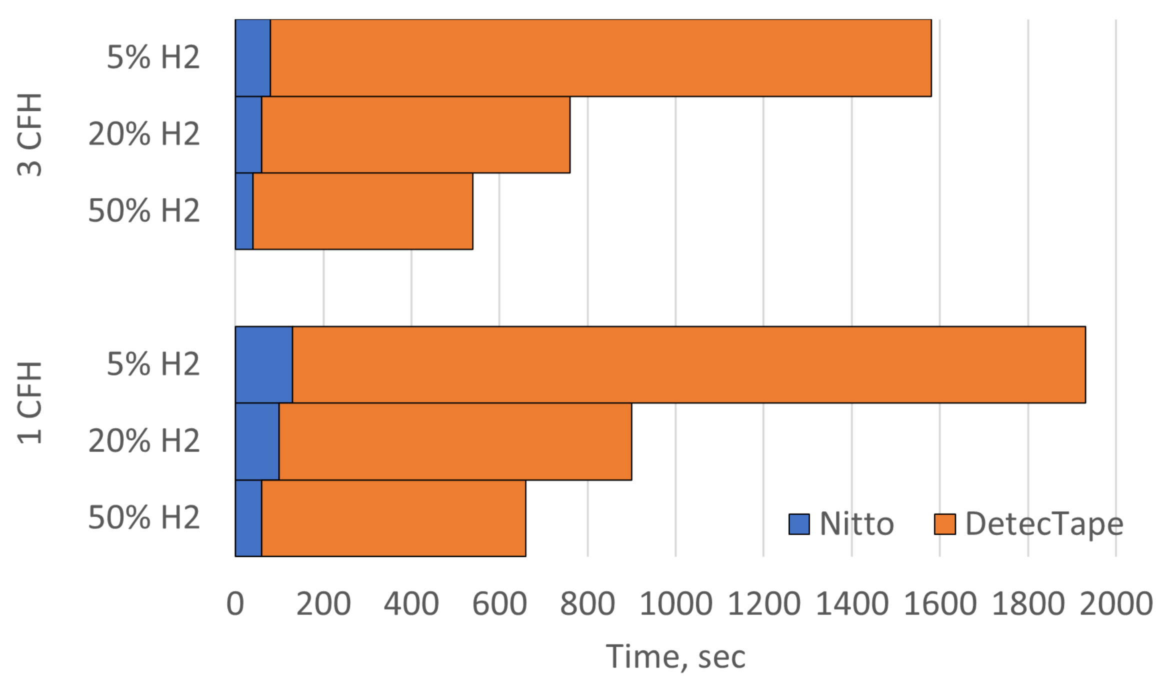

Figure 1. Reaction time to hydrogen blends.

Testing will include looking at:

- Various hydrogen blend concentration (e.g. 10%, 20%, etc.),
- Various hydrogen leak size (measured with flow meter at the leak sample inlet)
- Environmental conditions (different temperatures at the time of exposure to the leaking joint)
- Control testing (testing the tape's performance against false positives when a leak is not present)
- Long-term environmental testing (testing the tape's ability to withstand UV radiation, corrosion, outdoor conditions, etc.)
- GTI Energy uses time-lapse filming to provide illustrative demonstrations of the tape's color-changing process under various conditions, showing the duration of the color change. In addition to quarterly reports, a Final Report will be issued that describes all product testing and evaluation results, including a review of the report with the sponsors.

Results

In November 2022, two potential products to evaluate were selected. Work was initiated to develop the test matrix, as well as on a prototype test chamber for evaluating the tapes adhered to a fitting and exposed to various blends of hydrogen and natural gas. This was completed in the first quarter of 2023. In addition, sample fittings were flow tested to ensure consistency of leak rate.

In 2023, the team procured and assembled additional samples and initiated long-term outdoor testing, and UV exposure and performance testing. The team also tested samples with 5%, 20% and 50% hydrogen blends as part of the performance testing matrix. Additional samples for temperature testing at -23°C and 49°C were also prepared. Testing for long-term outdoor use as well as completed testing samples for UV exposure, and testing of samples with 5%, 20%, and 50% hydrogen blends has also been completed.

Status

All tests were completed in Q4 2023. The draft final report is scheduled to be prepared in Q1 2024.

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H2 Steel Compatibility

The objective of this project is to establish the effects on the material properties of pipeline steel when it is exposed to hydrogen.

Project Description

This project will build on literature reviews and previous paper studies, including OTD's 5.21.s Gap Identification Between H2 and NG; 6.14.b Hydrogen Blending, Phase 2; and PRCI 2020. Other ongoing and planned efforts from LCRI (Low Carbon Resources Initiative) will also be included in the updated literature review. Requirements of fitness-for-service from ASME B31.8 and B31.12 will also be addressed.

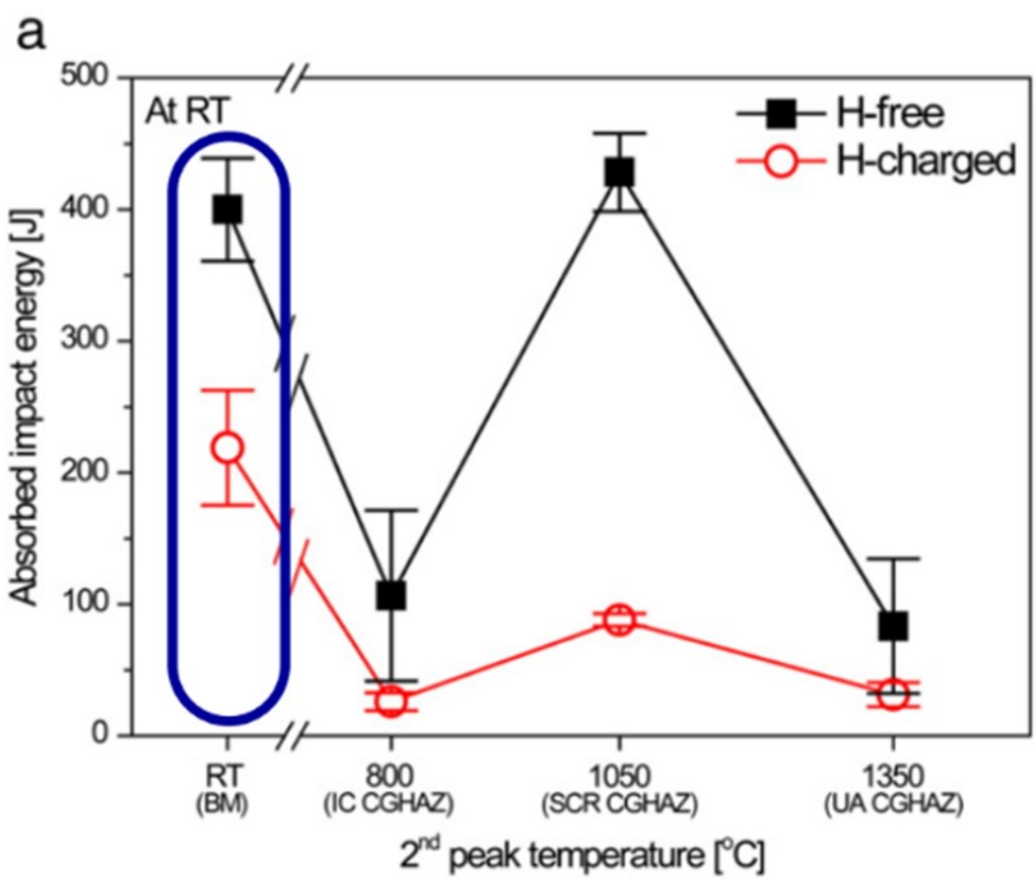
Recent research results have confirmed that impact toughness properties for steel are greatly affected by hydrogen, supporting the premise that more work is needed in this area.

The is an ~50% reduction in absorbed energy at room temperature for base metal (blue outline) in samples charged with hydrogen.

To deliver pure hydrogen safely to gas grid customers, compatibility of existing steel networks must be proven. Even small quantities of hydrogen affect mechanical properties of steel pipes. It is necessary to investigate and evaluate the steel compatibility with pure hydrogen to safely reuse existing gas networks for hydrogen distribution.

Deliverables

The deliverables of this project include a report of the updated literature review on the effects of



hydrogen on steel properties; a database with material properties for all tested samples, including the chemistry composition for those that were not fully characterized; a final report that includes an analysis of the project results, pipeline steel risk factors and potential impacts on engineering assessments; and a webinar for OTD sponsors to discuss the project results and if needed, a second webinar to provide any additional analysis and conclusions.

Benefits

As hydrogen gains traction to become part of the energy mix in a net zero future, using the US natural gas infrastructure to transport and deliver this gas can help facilitate its adoption. In the future, pure hydrogen networks could represent one of the solutions to decarbonize the gas grid.

Technical Concept & Approach

There are several technical challenges identified to secure hydrogen distribution via existing gas grids such as material and equipment compatibility with pure hydrogen.

The scope of this project includes the following tasks:

Requirements and literature review update - Updated review includes current regulations and standards and the planned modifications for hydrogen injection (ASME B31.8, ASME B31.12, EIGA, IGEM, BS, CFR 192) and gathering all available data concerning the impact of hydrogen on steel pipes. This task will also include the latest experimental results from industry, laboratories, and academia. Test methods to obtain toughness properties with hydrogen effects through non-tensile tests are being reviewed.

Sample gathering and selection - GTI Energy has an extensive library of pipe samples although grade and chemistry information are unknown for many of them. Candidates with a high probability of matching the targets chosen by the sponsors are being tested for chemistry. Additional samples from sponsors are being collected. A total of 10 materials have been selected for further testing.

Material characterization - The selected samples will be machined to obtain tensile specimens of the base material. Baseline tensile tests in air reference for equivalence between methane and air] will be performed to confirm the grade (B, X42, X52...). A maximum of three pipe samples per grade are being selected to perform tensile tests under hydrogen. Charpy baseline tests will be performed for characterization.

Tensile tests in hydrogen - The selected pipe samples are being machined to obtain additional tensile specimens. The samples will be tested with hydrogen gas. This task includes gas analysis composition before and after a tensile test for certain runs as a quality check procedure. It is known that small quantities of contaminant materials can significantly affect the results. True stress-true strain curves will be obtained for each run.

Charpy tests with hydrogen conditioning - Charpy specimens will be conditioned in gaseous hydrogen and then tested on an instrumented Charpy tester. A hydrogen and temperature condition apparatus is being designed and constructed. Charpy testing will provide data that is crucial for fitness-for service (FFS) assessments. Detailed force displacement curves will be obtained for each test run.

Data analysis and impacts to safety - The data from the baseline and hydrogen tensile tests will be analyzed to establish the impacts of hydrogen on elongation, reduction in area, fracture surface and toughness understood as the area under the stress strain curve. The impacts on engineering equations and assessments from the results being described and quantified.

Results/Status

A total of 20 samples were screened through chemistry analysis, and 10 samples were selected for further testing. The Charpy tester was delivered in mid-December 2023, and Charpy testing began soon afterwards. Due to the departure of the co-principal investigator, a new team member is being brought up to speed and a revised schedule will be sent to project sponsors.

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Operations Technology Development

Market Study of 100% H2 Compatible Distribution Equipment

To facilitate a pure hydrogen network, the objective of this project is to perform a product screening identification and analysis study on hydrogen (H2) ready equipment (100% H2) at a worldwide scale, both commercially and under development.

Project Description

In the context of hydrogen grids development, it is necessary to identify the existence of H2 ready materials and discuss with suppliers the technical characteristics and the industry needs for these materials. A list is presented below:

- Valves: ball, butterfly, gate, excess flow.
- Pressure regulators
- Gas meters: turbine, diaphragm, rotary, thermal, ultrasonic, etc.
- Filters
- Seals: rubber, valve, gaskets
- Fittings: tees, pressure control, line stopper, service head adaptors, electrofusion,
- mechanical couplings, flanges
- Sensors: leak, pressure, temperature, flow
- Compressors
- Calorific value instruments (CO, N2, CH4, H2O, Ar, O2, and CO2 as potential impurities)
- Heaters
- Pumps,
- Odorizer equipment

Gas grid operations of the various distribution operators are not necessarily similar, andvarious equipment, methods, and components are used. An inventory of the equipment and components used by project members is necessary to understand the full range of operator needs. This project is addressing those needs.

Deliverables

The deliverables are a final report summarizing all literature reviews, product screening and analysis done on H2 ready equipment, and summaries of conversations with suppliers.

Benefits

Pure hydrogen networks could represent one of the solutions to decarbonize the gas grid. Several technical challenges are identified to secure hydrogen distribution via gas grid networks such as material and equipment compatibility with pure hydrogen. Through this project, the project team will focus on network equipment & fittings.

Technical Concept & Approach

Literature Review and Operator Requirements Capture

This task intends to gather all information on equipment and components compatibility with pure hydrogen based on:

- International literature review and previous studies/OTD projects
- Interviews with relevant stakeholders, such as distribution operators and suppliers
- First-hand knowledge of OTD project members

Market Study

This task will identify a pool of suppliers with H2 ready product that could be used for demonstrator projects, assessing the interest of the suppliers on the development of this H2 ready equipment.

To achieve this market study, the following tasks are identified:

Interviews with suppliers, universities, and R&D centers with the objective to identify the technical characteristics of H2 Ready equipment that are commercialized or under development.

More precisely, information gathering will include:

- Supplier
- Type of technology
- Technological readiness level (TRL)
- Main technical specifications: Components, Lifespan, reliability
- Operation procedures & utilities that are needed to operate this equipment
- Maintenance procedures
- Norms & Standards & certifications
- Hydrogen ready technology roadmap (short- & mid-term)

Results/Status

In 2022, the project team initiated the literature review of external resources and previous OTD projects for metering equipment and sealants. In 2023, an agreement was made to focus vendor communications and interactions within the United States, United Kingdom, and Germany, given the more advanced hydrogen technology development in these areas.

The project team is finalizing the subcontract agreement to perform the supplier interviews and other activities identified under the market study. The project is anticipated to be completed in 2024.

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Screening Remote flow Monitoring and Control

The goal of this project is to perform a review of the technological state-of-the-art on smart and remote equipment to monitor and control flows on gas distribution systems.

Project Description

The need to monitor and control the blending of "green gas," such as biogas or hydrogen into existing gas distribution systems is the driver for this research. The review will cover three primary areas of technology to: control, throttle, or stop the flow of gas into a system; measure the flow and derive the total volume of gas injected into the system; and monitor the constituents of the gas for quality assurance.

In addition to enabling green gas mixing, these remote technologies can provide operators with improved situational awareness and a means to quickly react to developments in their gas distribution systems.

Deliverables

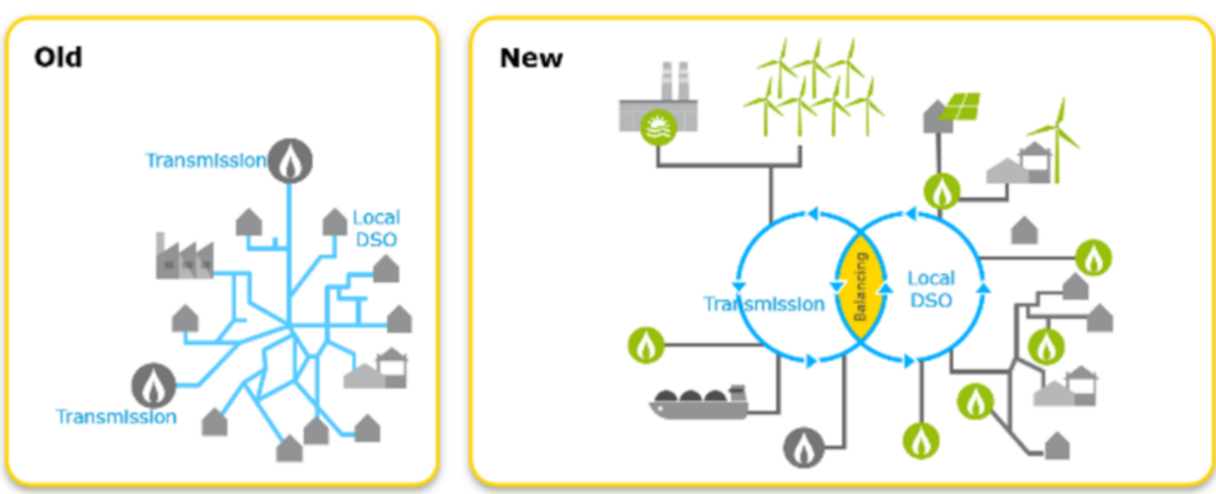
A final report that summarizes GTI Energy's review on remote flow control equipment and a on the exchanges between suppliers and project leaders.

Benefits

The increasing use of biogas and hydrogen as a means of offsetting greenhouse gas emissions changes the role of local distribution system operators (DSO). The historical role of the DSO is to deliver gas from a small number of transmission operators to the customer. The new role includes collecting and balancing multiple injection sources, including green gases that may not available 24/7. New technologies are needed to ensure the DSO can efficiently balance customer load and multiple sources. Smart and remote technologies will help optimize the use of diverse gas sources in the network

Implementing remote equipment to monitor and control gas flows reduces the time to perform changes (e.g., flow and pressure between winter and summer) versus manual intervention. It will also minimize the personnel required to complete work in inclement weather and other emergency situations. Also, the ability to remotely operate the network in real time is needed to optimize the blending of green gas. This will also improve the installation and operating costs of green gas sources.

In the future, it will be beneficial to anticipate



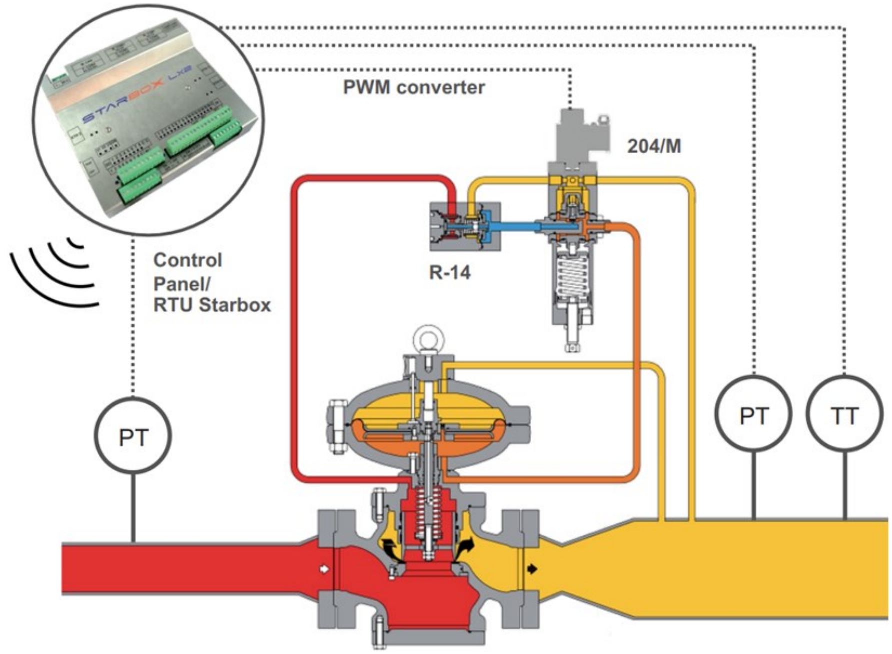
Increasing Sources of Gas Available to Local Distribution System Operators changes in gas pressure, flow, and consumption on the network. A smart network is needed to react to these situations and balance the injection of green gas.

The future network capabilities are:

Ability to react to measurements and data from the field to optimize operations and maximize injection of green gas into the network throughout the year.

To perform flow management, coordinating and adjusting short-term and day-to-day settings, to guarantee the proper balance between multiple gas sources and consumption.

Evolve and refine its operating rules according to the time of year.



Schematic View of Typical Smart Regulator Installation

Predict potential events and actions to ensure safe green gas injection in any situation.

The first step to put these new capabilities into practice is to implement into the network equipment that can gather data and is able to react on command. This survey of equipment will allow the industry to have an up-to-date market list and identify any technical gaps between industry needs and market product.

Technical Concept & Approach

After gaining insight into the sponsors' needs, the team will conduct a market study to review the worldwide technological state-of-the-art on remote gas flow monitoring and control equipment. It will also perform screening of what is commercialized on the market versus what is under development and collect feedback on the use of these from a technological and operational point of view, including operating and maintenance costs.

Results/Status

A survey was conducted of providers that offer remote control and monitoring solutions for district regulator stations. District regulators, or regulator stations in general, are the most prevalent hardware for controlling the injection of gas into a distribution system. This approach was taken to identify off-the-shelf hardware that could be used at points where green gas would be blended into the overall gas system.

Companies and suppliers were evaluated to gather additional information and further the understanding of their offerings. Specifications on each smart device, including supplier availability, technology readiness level, and communication options, were obtained. Based on the research team's assessment, a subset of these companies have market-ready technologies, while others are in development.

The team also completed its initial literature search for remote flow monitoring and control technology. A report and presentation on the findings were prepared for sponsors.

The project sponsors and GTI Energy are planning a virtual meeting with a vendor to better understand their remote flow monitoring and control equipment commercially available. The purpose of the meeting is to exchange information that would enable the vendor to prepare a realistic bill of materials and cost estimate for an installation.

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OTD Operations Technology Development

Insertion Valve for Gas Mains

The objective of this project is to perform a detailed needs analysis and survey the current marketplace. This involves identifying existing line stopping solutions and exploring technologies and equipment from other industries that could be easily modified. Our goal is to find better alternatives for inserting a valve into a live gas main than the current options available.

Project Description

The gas industry continues to seek new technologies to stop the flow of gas for active or distribution pipelines that are in operation. This project aims to assess the feasibility of using insertion valves which are typically used for isolating water pipelines, to be used for gas industry applications. The results of this project could yield an other alternative to safely stop the flow of gas without impacting safety and reliability of gas distribution networks.

Deliverables

The deliverables for this project will include a needs analysis describing the requirements/ needs of the project sponsors, a report that describes results from surveys of the insertion valve marketplace, including manufacturer product information, and a final report summarizing project findings and how they may be applied by sponsors, discussed on a close-out webinar.

Benefits

Current line stopping equipment and fittings are large, may be costly, and time-consuming to install. Utilities need quick-to-deploy, and easy-to-implement tools to aid in responding to and mitigate the impacts of natural gas emergencies. Such improved line stopping solutions may offer more efficient shutdown operations, thereby minimizing safety risks and reducing methane emissions. Utilities are required to respond to gas events and elevated pressure gas main situations and resolve them effectively and efficiently.

Systems that enable a valve to be installed anywhere along the gas main would be extremely advantageous to the industry in several situations. These use cases include scheduling future work, particularly on large diameter mains where bolt-on fittings are already in use, carrying out maintenance procedures to replace malfunctioning important valves, and executing gas shutdowns to prevent significant system failures.

Technical Concept & Approach

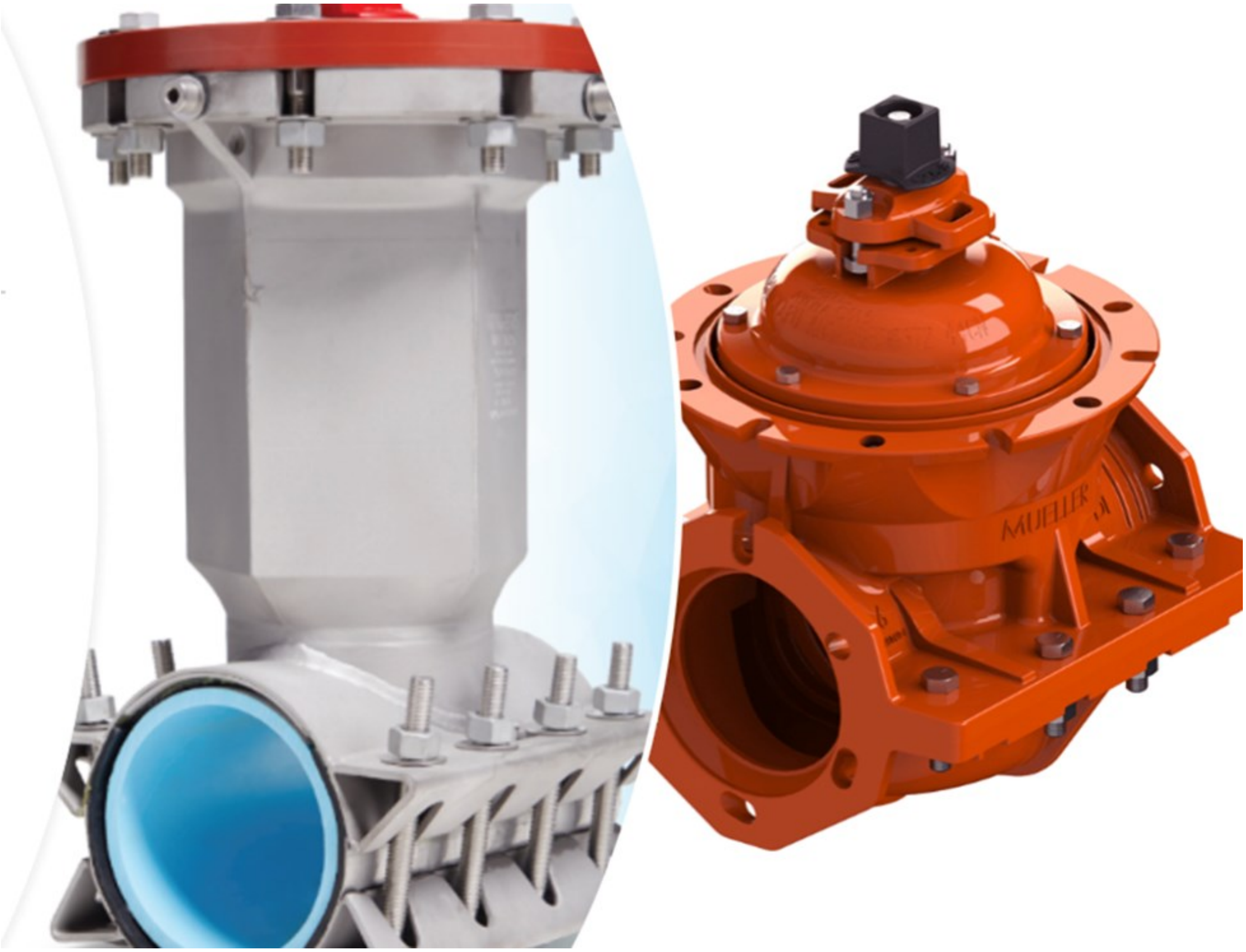
The methodology for this study includes a thorough investigation of insertion valve manufacturers and companies offering these valves' installation services. With the help of these surveys, to the project team can create a comprehensive market study and identify companies that may be able to provide solutions. The project team will evaluate each potential solution against a number of requirements, such as technical requirements, compatibility with current infrastructure, and other constraints.

to this review will help the project team obtain insights into new trends and breakthroughs in the insertion valve industry in addition to identifying viable solutions by exploring the options from various manufacturers and service providers.

Specific tasks will include:

Determine Utility Requirements

The project team is working with project sponsors to understand their requirements and desired capabilities for a line stopping insertion valve. The team will capture needs, applications, use cases, and other system attributes.



Insta-Valve 250 by Hydra Stop (left) and PermaSeal by Mueller (Right).

Survey Insertion Valve Product Market and Identify Potential Solutions

The project team will investigate the insertion valve marketplace to determine what, if any, natural gas insertion valve solutions currently exist. Additionally, the team will evaluate different possibilities if an insertion valve that fits the gas industry's needs or one that could be easily modifiable is found and what would be the next steps to follow. If a market-ready solution is not available, the project team will outline next steps to identify a potential solution.

Results/Status

Numerous interviews were held with different manufactures and companies that offer installation services for insertion valves for the water industry. The project is still ongoing and is anticipated to be completed in 2024.

The team is currently focused on surveying valve manufacturers and installation companies.

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Operational Data Through Connected Sensor Technology

The objective of this project is to identify and investigate currently available wireless sensors applicable to natural gas operations. The accompanying software and networks to aggregate and display the data is also being surveyed.

Project Description

The project team is researching and categorizing commercially available sensors that correspond to gas industry uses. The team will also provide details for a "proof of concept" implementation plan. Sensors for methane presence and gas pressure are excluded from this survey as they are covered in other projects as noted below.

Several OTD projects have focused on sensing for methane concentration and pressure monitoring. The OTD project "Methane Sensing Technology for 1st Responders" developed several technology prototypes with wireless connectivity. Several of these have been licensed for commercialization. The California Energy Commission co-funded the OTD project "Smart Safety Shutoff System" which makes use of wireless residential methane detectors (RMD) to trigger a shutoff valve. The RMD sensor testing and verification was substantially performed at GTI Energy labs. The current OTD project "Pressure Monitoring and Alert Devices" is investigating connected pressure sensors to augment relief valves in the field.

There has been an OTD effort to demonstrate wireless collection of cathodic protection (CP) data, such as pipe-to-soil potential and current density. There are existing devices that provide CP data over cellular networks.

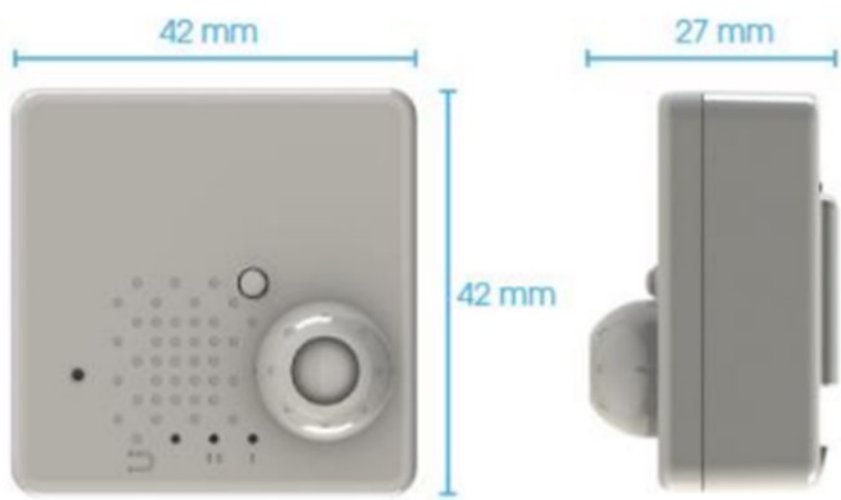
Deliverables

Deliverables for this project include:

- A report that catalogues connected sensors that reasonably fit gas utility requirements.
- A summary and ranking of these sensors relative to selected key performance indicators (KPI)
- Interfacing with the Wireless-Smart Ubiquitous Networks (Wi-SUN) Alliance; a global industry association devoted to promoting interoperability between various AMI equipment providers.
- A status update on Wi-SUN Alliance progress in certifying a battery-powered device(s) for gas utility needs.

Benefits

The evolving ecosystem of wireless sensors, communication protocols, and cloud services can provide utilities with day-to-day operational data to support decisions on natural gas safety and emissions reduction. The proper application of connected sensor technology can accomplish this at



LoRaWAN Wireless Temperature, Humidity, and Motion Sensor a lower cost than traditional SCADA (supervisory control and data acquisition) systems.

There are other categories of sensors, yet to be investigated, that can provide benefits to operators. Wireless sensors may be well equipped to:

- Detect the presence of water in unattended facilities/vaults.
- Open doors, gates, or general intrusion in remote facilities.
- Identify vibration/sound which may be indicative of equipment problems that require maintenance.
- Monitor/move valve stem position as an indicator of gas flow.

LoRaWAN Wireless Water Intrusion Sensor

Technical Concept & Approach

The project tasks are structured to investigate connected sensors that can be readily applied to gas distribution system needs. There are two distinct areas that are investigated: identifying available sensors of the appropriate types and verifying wireless network support.

Results/Status

During 2023, the project team investigated LoRaWAN compatible sensors for water presence and for occupancy/intrusion acquiring a few examples for further analysis and testing.

In the category of water detection, there are “rope” sensors and level sensors. Rope sensors detect water in direct contact with a cable style sensor. Level sensors use an ultrasonic sensor to measure the distance from the sensor to the surface of a liquid. A UK based company had a series of sensors that are rated for outdoor use with rugged enclosures. Some examples of these are a rope type water sensor, an ultrasonic liquid level detector, and a general-purpose device that converts 4-20 mA sensor signals into radio signals. Another vendor produces a series of “smart room” sensors that contain multiple sensors. All have temperature and humidity sensors embedded. Versions with motion detectors or switch contact inputs can be obtained. The versions shown are not rated for outdoor use but may be useful inside structures such as instrument sheds. The project team currently has samples in hand of the sensors. These will be tested using the GTI Energy campus LoRaWAN network.

A closer look at water level sensors was prompted by inquiries from utility sponsors. The need is to be notified of water intrusion into various facilities such as manholes or vaults. Several utility companies have water alarm systems that make use of float switches in pressure regulator vaults. In these cases, there was existing instrumentation to monitor the regulator functions. The float switch made use of extra channels in the existing instrumentation.

There are many regulator vaults, and other facilities, which do not have control telemetry in place. For these, a stand-alone system to monitor basic sensors may be advantageous. A product to facilitate one-off connections for a low number of sensors has been identified and was scheduled to be further investigated.

The project team continues to compile sensor information collected to date for inclusion in the project’s final report.

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Best Purging Practices for Minimizing Methane Emissions

The goal of this US Department of Transportation (DOT) Pipeline and Hazardous Materials Safety Administration (PHMSA) funded project is to research and establish best purging practices for the elimination or avoidance of methane emissions during pipeline construction, commissioning, and maintenance.

Project Description

The natural gas industry is subjected to increasing pressure from various agencies to curb carbon emissions as well as meeting internal company goals to reduce and/or eliminate methane emissions from day-to-day operations of their natural gas systems. The energy sector has become more conscious about the release of greenhouse gases with the rise in the scientific understanding of the contributors to climate change.

Challenges with identifying purging best practices are associated with the time and resources required to operate a successful purging operation with reduced or elimination of methane release. Venting gas is typically the most time-efficient method of purging a pipeline, however, ideal alternatives to venting can provide an economic incentive to the operator, while also saving time, resources, and addressing environmental concerns.

Figure 1: Pipeline purging operation

This OTD project is the co-funding for the above-mentioned PHMSA project.

Deliverables

- A comprehensive literature survey that identifies and details various methods to reduce and/or eliminate methane emissions due to purging and/or blowdown operations.

Figure 2: Gas venting to atmosphere during blow down operation

- A technology survey that will focus on already existing methods, improvements to these methods, and new technologies and techniques. The different alternatives will be described in relation to the operating scenario and environment as described in the American Gas Association's (AGA XK1801 "Purging Manual").
- A final report that includes operational recommendations and guidance to determine the best practices associated with each technique and method. The review of potential alternatives will also include economic examples and methane emissions avoidance quantification calculations to provide context for comparing the feasibility and benefits of different methods.

Benefits

Methane releases and emissions can occur in transmission, distribution, and gathering pipelines at any point across the system. To achieve decarbonization and climate change goals, the government and the natural gas industry are working to minimize methane emissions.

Avoidance of methane emissions from purging operations have both economic benefits for operators and environmental benefits for the community. Using alternatives to venting natural gas into the atmosphere also increases public trust in the natural gas industry and provides a safer work environment for pipeline and gathering system operators.

Technical Concept & Approach

The technical concept and approach will involve the following:

- A thorough review of literature, past, current, and planned research projects pertaining to pipeline purging methods and best practices will take place.
- The project team will provide detailed information about the operational procedures and challenges associated with each identified purging alternative.
- The project team will compile the attributes of the identified strategies and methods to reduce, eliminate, or avoid methane emissions during purging operations and provide recommended best practices for their applications in different purging scenarios.

Results

In Q4, 2022, The team administered the first of several surveys to collect information about purging methods used at various. In Q2, 2023, the project team reviewed available literature from various emission reduction equipment manufacturers and began a thorough analysis of the available data. Interviews were conducted with industry subject matter experts from manufacturers and gas operators that are using the equipment.

The team began conducting a review of alternative purging methods, including identification of the potential to mitigate methane emissions. Researchers provided detailed information about the opportunities and challenges associated with each identified purging alternative to sponsors. The project team continued interviewing industry subject matter experts in Q3 and submitted the draft final report in Q4, 2023.

Status

The project close out meeting and the final report will be submitted in Q1, 2024.

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Kleiss Stopper Increased Pressure Enhancements & Evaluations

The goal of this project is to expand the use application of the Kleiss Stopping System by supporting an increase in the pressures at which it operates; from the current 60 psig to 99 MAOP (maximum allowable operating pressure).

Project Description

Previous OTD efforts to evaluate and test Kleiss solutions have occurred under Project 5.12.g - *Large Diameter High Pressure (60 PSIG) Inflatable Stoppers – Evaluation of Kleiss MCS60 -1016 System for Natural Gas Industry, Phase 2.* The project team worked with Mainline Control Systems (MCS) and Kleiss to evaluate and test existing inflatable stopper technology capable of stopping off system pressures of 60 psig at pipe diameters of 10 inches to 16 inches. This project builds on that work through the design, development, and testing of a new stopping system that can be used for system pressures up to 120psig, and for pipe diameters up to 8 inches.

Deliverables

The key deliverable for the project will be a final report that describes the test results for the newly designed and developed 120 psig flow stopping system and provides recommendations for any identified future system enhancements.

Benefits

Current benefits being realized by utilities from the Kleiss systems include their applicability for multiple pipe materials (PE, steel, cast iron, and PVC pipes), lightweight equipment sizes, and operational consistency. Increasing the operating pressure will allow utility companies to expand their use of the flow stopping systems for most pressurized pipe applications.

With aging equipment, difficulty in finding replacement parts, and issues in receiving prompt delivery of fittings, the introduction of the high pressure rated stopping system will supply pipeline operators with another option for continued, more efficient operations within their systems.

Technical Concept & Approach

The scope is for the project team to work with Kleiss and their North American distributor MCS on advancing the development of their current stopping system to support higher pressures. More specifically, efforts will focus on the redesign of the flow stopping tower and MDS stopper for higher pressure operation. The project team will work with OTD sponsors to understand their needs and desired

Figure 1. Kleiss stopper system controlling system flow on PE piping systems

Figure 2. Kleiss MDS stopper

Figure 3: Kleiss MCS60-38 Stopping System

capabilities for an increased pressure stopping system. Important considerations will include the necessary pressures, pipe diameters, and material types needed by sponsors to satisfy their requirements.

Additionally, the team will work with Kleiss to examine higher pressure concepts in greater detail and describe the benefits of an elevated pressure system for the natural gas distribution operating environment. The team will also facilitate a survey of the current Kleiss product offerings to identify those that most closely match the sponsors' needs. The project team will partner with Kleiss on the design and development of the flow stopping tower and MDS stopper to support higher pressures. The team will leverage a continuous evaluation and feedback mechanism to ensure the design meets the sponsors' requirements. The project team will conduct testing of the newly developed increase pressure rated system. Testing results will be reported to all project parties and needed modifications will be prioritized by severity of operational impact.

Results

In 2023, the project team facilitated system design and development discussions. A preliminary design document was drafted to capture proposed system modifications to support pressures up to 120 psig and a Failure Mode and Effect Analysis was produced for the tapping and flow stopping processes. Additionally, the team began sourcing PE fittings for 6 inch and 8 inch pipe.

Status

Work continues on the design and development of the solution to support system pressures up to 120 psig, Testing is planned to begin in 2024 Q3 with project work completing in early 2025.

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Project No. 5.23.h

Expanding Hydrogen Storage to Porous Rock Formations: A Framework for Estimating Feasibility and Operational Considerations

The goal of this project is to demonstrate the feasibility of large-scale underground hydrogen storage (UHS) in aquifer-type porous rock formations through bench-scale experiments and field-scale dynamic reservoir simulations.

Project Description

The goal of this project is to demonstrate the feasibility of large-scale underground hydrogen storage (UHS) in aquifer-type porous rock formations through bench-scale experiments and field-scale dynamic reservoir simulations.

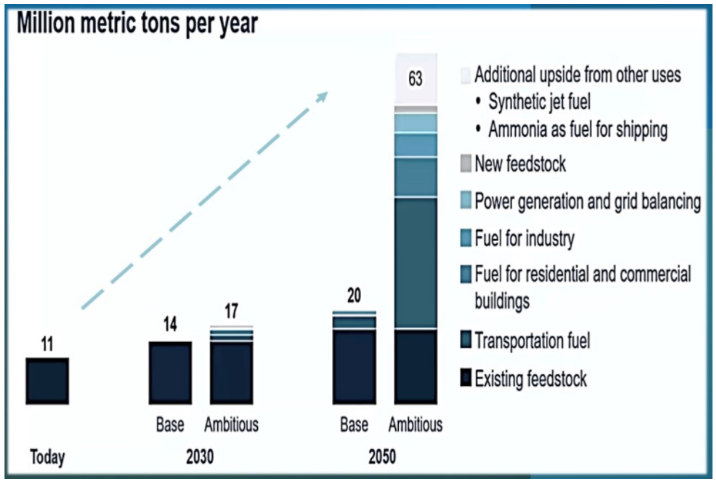
As part of the project, the team will be creating a framework that helps the industry with identifying suitable aquifer formations for underground hydrogen storage sites as well as recommendations for controlling and monitoring hydrogen (H2) movement and loss within the UHS reservoir.

Deliverables

Deliverables for this project include: an analysis of modeling and results, the development of a framework to identify suitable aquifer formations, and a final report.

Benefits

Hydrogen is anticipated to become a pivotal energy carrier in future, offering flexibility and balancing capabilities across various sectors. While its generation from wind and solar energy presents promising applications in electricity, heating, transport, and industry, large-scale underground storage of hydrogen will be crucial for ensuring secure and affordable supply as reliance on renewable sources grows. While subsurface reservoirs like gas fields and salt caverns have long been used for storing natural gas, research into the storability of hydrogen in these formations is ongoing. Although initial findings suggest viability, significant steps are needed before underground hydrogen storage can be upscaled and commercialized.



Experimental and modeling findings regarding hydrogen storage in sandstone aquifers and shale caprocks, typical of those found in the US Midwest, will inform the development of Guidelines. These Guidelines aim to assist gas utilities, storage facilities, and regulatory bodies in evaluating the likelihood of hydrogen movement and loss, considering factors like formation type, caprock sealing, geochemical reactions, and multiphase hydrogen flow with formation fluids.

Technical Concept & Approach

Characterize Reservoir Performance

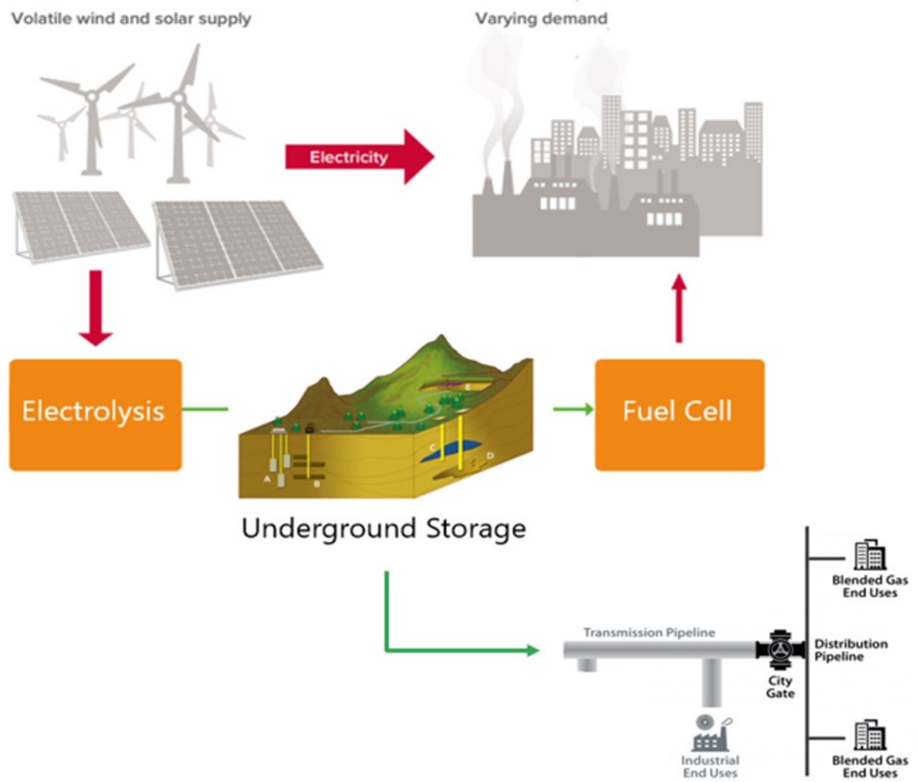
Conduct detailed experimental work on caprock sealing and hydrogen dispersion in the reservoir and evaluate possible in-reservoir H2 losses due to solubility

Run Modeling and Simulation

Fine-tune models with experimental data and run multiple injection scenarios to apply sensitivity analyses and improve long-term reservoir performance estimates over months/years.

Develop a Framework

Develop a set of guidelines to assess the suitability of porous rock UHS in aquifers. Incorporate the American Petroleum Institute (API) underground natural gas storage standards, operational considerations for preventative or mitigative measures to reduce HS gas loss, and best practices to monitor H2 gas loss within the storage boundaries.



Renewable Energy Integration- Opportunity to store surplus energy during periods of excess generation.

Results/Status

In Q2, 2023, the project team performed detailed reviews of existing UHS technologies and experience as well as the available geologic storage reservoirs, various storage types, advantages and disadvantages of different geologic storage, and technologies that need to be adapted or evolved for the UHS. Over 60 scientific articles and technical reports were reviewed and consolidated into a "State of the Technology" report that will be provided with the final report.

In coordination with the Illinois State Geological Survey (ISGS) and the University of Illinois (UofI), the project team completed the core selection (from the Ironton/Galesville reservoirs) and core specimens preparation process.

Using the information gathered from the project partners, an interim report was developed to summarize the experimental design and core sample preparation progress. This interim report also highlighted preliminary equipment testing and core analysis data and was shared with OTD members in October 2023.

The team is currently continuing H2 flow-through experiments including H2 injection in the reservoir core samples, monitoring pressure evolution through the core sample for both brine and gas, monitoring the flow rate of brine and H2, calculating the relative permeability of H2 in brine, incorporating experimental results in the forms of dispersion parameters into the modeling, and running multiple injection scenarios to perform sensitivity analysis on the simulation results.

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OTD Operations Technology Development

Safety Hazard Modeling of 100% Hydrogen Pipelines

The goal of this project is to measure and compare the impact to risk from potential hazard scenarios occurring on 100% Hydrogen (H2) pipelines to methane pipelines. This will help natural gas pipeline operators better understand the differences and as necessary, make changes to their operations, maintenance, monitoring, and processes to maintain pipeline safety.

Project Description

As part of decarbonization efforts, natural gas operators in Europe are planning for potential conversion of natural gas infrastructure to 100% hydrogen. Operators are experienced with and have procedures for dealing with hazards from operating natural gas transmission and distribution pipelines. To better prepare their pipeline operations and maintenance (O&M) and safety procedures for conversion to 100% hydrogen, operators need to understand how to maintain pipeline safety .

A goal of this project is simulate a pipeline leak and understand the potential risks associated from this event.. In this project, the outcomes for 100% hydrogen pipelines are compared to 100% methane gas pipelines (as a proxy for natural gas) to assess impact to risk .

Deliverables

A final report will be delivered detailing the computer simulation modeling results and recommendations.

Benefits

To plan and prepare O&M procedures for the conversion to either blended hydrogen or 100% H2 gas grids, project sponsors need to better understand the pipeline safety hazards regarding this type of operation. Therefore, this project will carry out pipeline hazard simulation modeling of blended and 100% H2 pipelines and compare against equivalent relevant natural gas pipeline hazards. Once hazard models are developed and understood, operators will be better prepared to plan future updates to their pipeline safety measures & procedures.

Technical Concept & Approach

The project team will meet with sponsors to discuss and determine the simulation requirements, scenarios, and parameters, and provide a final report documenting the simulation modeling results.

Results

In Q1 2023, the project kickoff meeting was held with project sponsors, and sponsors identified their desired parameters for simulation (e.g., pipe diameter and operating pressure). The results of this

Table 1: Requested ALOHA simulations

Pipe Diameter	Operating Pressure(s)
6 in (150 mm)	100-psig (689 kPa) 150-psig (1,034 kPa) 200-psig (1,378 kPa) 250-psig (1,723 kPa) 300-psig (2,068 kPa)
8 in (200 mm)	150-psig (1,034 kPa) 250-psig (1,723 kPa) 300-psig (2,068 kPa)
10 in (250 mm)	300-psig (2,068 kPa)
12 in (300 mm)	150-psig (1,034 kPa) 200-psig (1,378 kPa) 250-psig (1,723 kPa) 300-psig (2,068 kPa)
16 in (400 mm)	300-psig (2,068 kPa)
20 in (500 mm)	300-psig (2,068 kPa)

The original project scope planned for the hydrogen pipeline hazard modeling simulations to be run using the ALOHA software platform, which models above-ground leak scenarios. Methane pipeline simulations are also run in ALOHA (as a proxy for natural gas pipelines which are not directly available in ALOHA). The project team also added the HyRAM+ software platform to the scope, which provides built-in capability for modeling blended gas scenarios.

Project sponsors were also interested in modeling below-ground leak scenarios. The project team confirmed that neither ALOHA nor HyRAM+ has this capability, and the team would need to evaluate a different software platform, COMSOL, for modeling below-ground leaks. This was excluded from the current project scope.

15 pipe diameter and pressure parameter combinations from above were run for the 5 different types of hazards, for a total of 75 scenarios. Each of these scenarios yielded 3 different threat zone distance results.

Results from both software tools will be provided in the final report.

Status

The draft final report is being prepared and is scheduled to be issued in Q1 2024.

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Material Inspection and Testing Training Program

The goal of this project is to create a standardized comprehensive training program using visual aids (videos and interactive 3D models) to inspect and test purchased materials and components used in Gas Operators' systems.

Project Description

To manage risks associated with products that may not meet a company's requirements, utilities implement processes for qualifying materials and routinely inspecting and testing them before they are placed in service. Inspection of purchased materials has become integral to the daily activities of the operators' companies. If implemented effectively, it improves the detection of deficient products before they are installed in the system and reduces the risks to safety, reliability, and the public. It is not trivial and can produce different results if performed incorrectly.

Inspection and testing require skill and product knowledge that can be achieved by developing skills-based training programs to help a company's employees perform their duties better and achieve competency and consistency. The project team will partner with manufacturers who have expertise in their products' fit, form, and function to provide input and guidance on the content of this training material.

Dresser Style 90 Mechanical Fitting Assembly

Deliverables

Deliverables for this project include a list of product types to develop training content for performing material inspections, Up to 20 published training modules, quarterly update reports and a final report summarizing the project deliverables and reviewing the training content with the sponsors.

Benefits

Participation in this program will establish a standardized, comprehensive training content to preserve knowledge and create consistency and repeatability in inspecting and testing of purchased materials and potentially while reducing risks of operational errors in identifying a defective product.

Technical Concept & Approach

The project team will create 15 to 20 micro-videos supplemented by 3D interactive models in collaboration with subject matter experts and visual content developers. Quizzes will accompany each training module to gauge training effectiveness and comprehension. All developed training content will be accessible using mobile devices, tablets, and office computers. The training content will reside in the GTI Energy platform.

Results/Status

The project team created and submitted a survey to identify product types. Based on the responses and experience with the OTD 5.17.g Material-Supplier Quality Assurance program, a list of product types was identified to develop inspection training content. The project team has defined and submitted a scope of work to vendors for the creation of 3D models and videography.

The project team will be reaching out to manufacturers to get their support in helping to create training content. The team will finalize the quotes with vendors, assemble agreements, and collect utilities' product inspection procedures to understand how end users inspect their materials. The project team will begin creating training content (storyboards) for videography and work with a 3D modeling vendor.

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Developing Acceptance Criteria for Mechanical Tapping Tee Anomalies – Phase 1

The goal of this project is to evaluate the condition of exhumed PermaLockR mechanical tapping tees installed in gas distribution systems and develop guidelines to determine if they pass or fail inspection criteria.

Project Description

An operator was proactively performing excavations within a subset of its service territory to evaluate its PermaLock tee fittings and better understand the potential impact to the operator's system risk such fittings may pose.

1. This project was developed to help natural gas operators:
2. Evaluate the condition of the exhumed PermaLock tee fittings;
3. Develop field acceptance criterion;
4. Determine whether the PermaLock tee fittings can be remediated; and
5. Propose a plan to analyze and develop an approach to address improperly installed PermaLock Tee fittings.

Phase 1 looked at examining and evaluating a subset of PermaLock tee fittings attached to main pipe, and Phase 2 is intended to integrate the data from Phase 1 into an advanced fault tree analysis model that would aide operators in better understanding the impact of these fittings to their respective system risks.

Deliverables

The objective of the overall project is to develop a field acceptance criterion based on different levels of inspection evidence, and to develop a potential approach for the analysis and remediation of PermaLock tee fittings. Once developed, this criterion could provide guidance for operators to evaluate component anomalies and, if needed, determine appropriate remediation.

Benefits

Operators are continue taking steps to identify, review, and mitigate potential risks associated with different fittings. This project is to assist in determining potential risks with these installed fittings and possible remediation options to address potential risks and develop a field acceptance criterion.

Technical Concept & Approach

Fitting samples will be exhumed and shipped to the team for further evaluation. Additionally, a database will be developed for capturing identified anomalies with dimensioned photographic and X-ray exemplars of the anomaly.

Results

Sixty-one (61) samples were provided to GTI Energy and evaluated using external examination, internal visual examination, and CT X-Ray.

GTI Energy also developed a mobile data collection application to help consolidate sample data and system data for future analysis. This enables users to accurately identify the geographic location of each sample collected and record additional attributes about the sample.

Although none of the fittings reviewed within this project were found to be leaking, GTI Energy noted a variety of observations on the sample fittings. Further extensive data collection and analysis will be crucial to confirm these initial observations and understand their broader implications.

Status

Phase 2 will focus on evaluating additional samples to better understand the frequency of anomalies observed in the Phase 1 evaluations by gathering samples with variations in regional installation practices, environmental conditions across regions, and year of installation. Findings from Phase 2 will help inform how operators manage their system risk testing protocols designed to understand the impact of anomalies noted on the performance and expected lifetime of PermaLock tee fittings.

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Poly-Aluminum Composite (P/AC) Service Line Joining

The goal of this project is to investigate the potential of joining Poly-Aluminum Composite (P/AC) pipe to medium density polyethylene (MDPE) service tubing using electrofusion couplings.

Project Description

Commercially available electrofusion (EF) and mechanical couplings are not designed for use with Poly Aluminum Composite (P/AC) tubing. Prior to engaging with a manufacturer of these couplings with a possible need to consider a purposefully designed joining method, it is desired to first learn what issues may need to be addressed when dealing with the dissimilar tubing construction and material compositions. The proposed trial and error type of learnings will help in determining if there is a potential path forward or not.

Deliverables

The deliverables for this project include a list of new materials to test, sampling plan, and test methods; Interim EF and mechanical coupling joining results for review with the project sponsor; and a final report

P/AC pipes being joined by a MDPE electrofusion coupling

Benefits

Distribution service piping has changed over the years, from steel, to various types of plastics, and even composite piping materials. Operators are replacing these vintage materials overtime, however, until they have been completely replaced, they must continue to maintain and at times repair and/or connect these materials to modern day materials. The need exists for a more robust (non-mechanical) connection of these vintage materials to modern materials. The business value add for this project is to safely operate vintage and dissimilar piping systems which are connected to modernized pipelines and ensure connection and joining practices are sound.

Technical Concept & Approach

To ascertain if P/AC tubing can be effectively joined to MDPE tubing using electrofusion or mechanical couplings (with or without some form of encapsulation), it is first essential to determine if it is feasible to develop a reliable and repeatable method for preparing the fusion surfaces for these various joining methods. If a surface preparation method is found, fused assemblies will be prepared using various forms of currently accepted joining methods and commercially available fittings.

Results/Status

In 2023, two electrofusion coupling assemblies were successfully prepared without encountering any issues.

To ascertain if P/AC tubing can be effectively joined to MDPE tubing using electrofusion couplings, a segment of an exhumed P/AC pipe was dimensioned, prepared for electrofusion joining, and fused assemblies made with MDPE and HDPE electrofusion couplings. No issues were encountered during the fusion operations. Subsequent testing of the joints displayed 100% ductility, indicating that both fittings made good joints with the P/AC pipe.

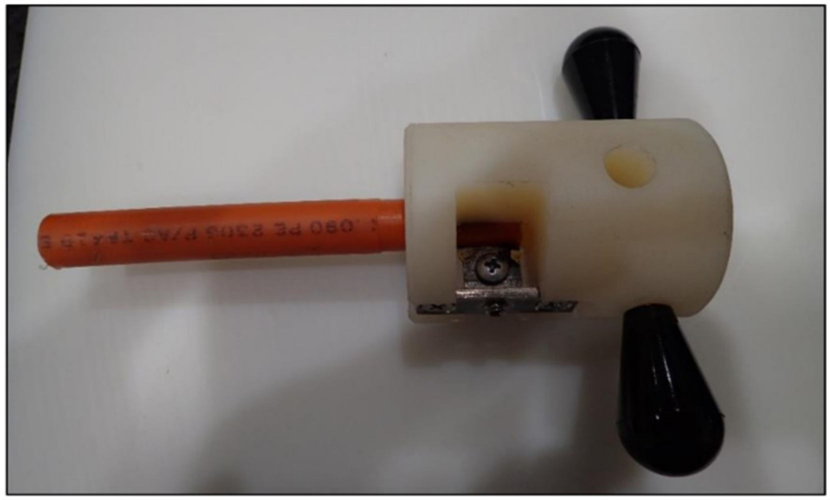

Figure 1. Pipe sample preparation, peeling/scraping

Project sponsors were briefed on the initial evaluation of electrofusion couplings testing an evaluation. The evaluations of the joining method were performed via the ASTM F1055 Fusion Evaluation Test (FET).

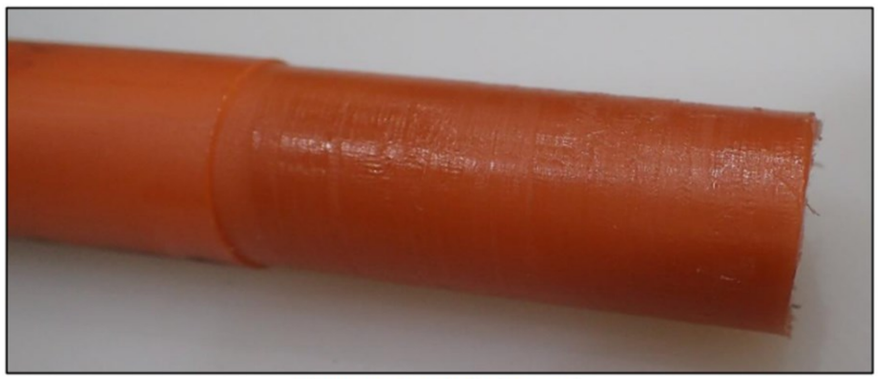

Figure 2. Peeled pipe end

The project team requested additional lengths of P/AC pipe to be provided, as well as the make and model of an electrofusion fitting that the sponsor would like to have evaluated.

The team is awaiting additional materials and will initiate evaluation of the fused assemblies by performing lifetime prediction testing once they are received.

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OTD Operations Technology Development

Guidance for H2/NG Blending Equipment Installation and Operations

The goal of this project is to utilize the latest hydrogen research and information on natural gas blending technology to create guidance on hydrogen blending which operators can include within their procedures.

Project Description

The natural gas industry is seeking cost effective and safe ways to reduce the carbon footprint. Hydrogen produced through clean energy pathways can be injected into natural gas pipelines, and the resulting blends can be used to generate heat and power that lower emissions. As operators are planning to implement hydrogen blending in their systems, there is a need to develop guidance documents such as new operating and maintenance procedures and recommended practices. There is also a need to estimate the anticipated investment amounts needed to implement and operate hydrogen blending projects.

Deliverables

Deliverables for this project are:

- A summary of hydrogen equipment required for injecting hydrogen into existing natural gas pipelines and the current capabilities of commercially available equipment.
- Financial considerations and estimated capital and operating costs to implement hydrogen blending projects providing the process of how to create an estimate.
- A final report white paper documenting hydrogen blending recommended practices and operating procedures for required equipment.

Benefits

Hydrogen blending is a decarbonization pathway for natural gas operators. The energy industry is seeking recommended practices pertaining to safety, equipment, and operations for a blended gas system. Additional guidance on considerations for updating existing procedures, as well as financial considerations for blending projects can help operators in their design process, decisions for new investments, and continuing to maintain pipeline safety.

Technical Concept & Approach

The project will:

- Meet with equipment (ie. Electrolyzers, blending skids) manufacturers, industry subject matter experts and other relevant stakeholders to gather information for operators to consider when setting up equipment and injection site to introduce blended hydrogen into their gas distribution system.
- Highlight the procedures for the installation of required blending facility equipment.
- Feature the continued blending operations and maintenance requirements within the blending facility.
- Evaluate potential hydrogen end use for any excess hydrogen production (e.g., hydrogen fuel cells to support microgrids or to provide on-site power, hydrogen supply for refueling stations).
- Gather information from commercially available blending equipment providers and provide a financial estimate of the associated equipment and operational costs (e.g., utilities, maintenance).

Picture of Fuel Cell Energy's Electrolyzer

Results/Status

The project team has begun interviewing various electrolyzer and blending system manufacturers and gathering information related to their products, technical details, and equipment cost estimates.

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OTD Operations Technology Development

Evaluate the Effects of Long-Term, Elevated Temperatures on PE Pipe Service Life

The goal of this project is to develop and assess a model to estimate the remaining service life of polyethylene distribution (PE) pipe currently in the ground based on age, temperature of soil, and other attributes.

Project Description

Much PE pipe currently in the ground is approaching the 50-year manufacturer projected lifetime. There are also areas where, despite being buried, the pipe has long-term exposure to elevated temperatures. The challenge for utility operators is to determine when a particular section of a PE system needs to be replaced or retired. There are several heat exposure scenarios that can accelerate the aging of PE pipe and shorten the service life:

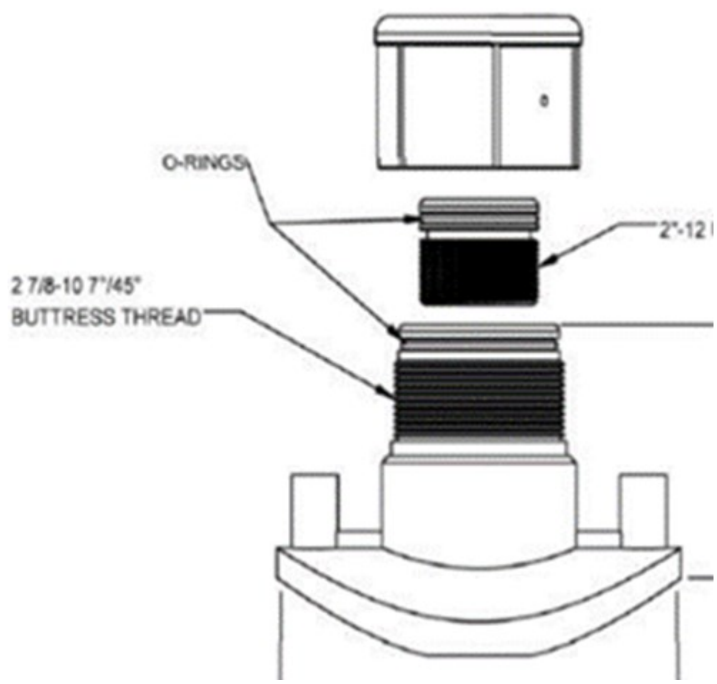
- continuous exposure to high temperatures, such as adjacent steam lines (which has previously been explored by GTI Energy),
- elevated ground temperatures, and
- locations in distribution systems where low or no-flow conditions can exist for extended periods. Normal gas flow provides some cooling to the PE material.

Additionally, OTD members have raised specific concerns to consider when evaluating the elevated temperature impact to PE Pipe, which are being incorporated into this project:

- Impact on gas temperature from warmer soil temperature as cooler gas moves downstream of the regulator.
- Flow impacted by local pipe geometry, such as loops or dead ends may negate cooling from the gas.

Deliverables

- Develop a model to estimate the remaining service life of PE and a description of its data requirements.
- An assessment of how additional data would improve the ability of the model to predict the remaining service life.
- Deliver systems to sponsor test sites to collect soil temperature. This can include retrieving samples of PE from in-service pipes and measurements of gas temperature and flow.
- Summary of sample analysis data.
- Final reports and presentations that address comments or concerns.



Versa Tap Fitting to Collect PE Sample Coupons

Benefits

There is currently a gap in having a model or methodology to identify where remediation may be needed based on the age of PE pipe and soil temperature. Having this information can be helpful to the industry as a large population of PE pipes in the ground is approaching the 50-year manufacturer projected lifetime. Having accurate remaining lifetime data will help operators use risk-based approaches to drive funding and the scheduling of remediation for assets (PE pipe).

Technical Concept & Approach

The first project step will be determining what samples of aged PE pipe removed from service the utility sponsors already have in hand. Collecting data on soil temperatures near PE pipe in the ground will also be required. Retrieving in-situ samples of the PE material for testing and acquiring measurements of flow inside the pipe would improve the accuracy of the model. Retrieving samples would require some operations on live PE pipe, a larger effort than acquiring soil temperatures.

If additional data is needed, samples of PE from live gas pipes could be retrieved using a tap fitting that would allow a cutter to remove a circular coupon of material from the pipe. The fitting provides a way to seal the opening afterwards and provides a potential method to place sensors in the gas stream to monitor flow and temperature.

The project team will perform a literature search and study of long-term heat-induced aging of PE. This will be combined with deployment of sensors in the field to collect soil temperature, moisture, and other parameters to inform the study. The team will deliver a model to accurately estimate the impact of sustained high temperatures on PE lifetime in various scenarios. Recommendations for PE specimen testing will also be developed.

Results/Status

The project commenced in the third quarter of 2023. A key focus was establishing the availability of existing samples and their history. Once samples are identified, the project team intends to place in-soil temperature and environmental sensors at the locations where the samples were obtained and test the samples for remaining service life.

The team also discussed that PE coupon samples would be collected from the field, and processed to better understand material properties that may impact the lifespan.

The project is ongoing.

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Updating Unaccounted-For (UAF) Estimates in the Distribution System

The goal of this project is to identify the factors contributing to 'Unaccounted-For' (UAF) gas volumes in distribution systems, determine the root causes, develop methods and procedures for quantifying the contributions of each cause, and suggest actions and practices for their reduction.

Project Description

UAF is the difference between the measured volume of gas received into the system and the measured accounted-for volume delivered. These differences are commonly due to system gas leaks, purging, company usage, and the effect of data measurements and reporting. (The term 'LUAF' was used in earlier studies in the 1990s for determining lost and unaccounted-for gas volumes and it is also used in this study to include all the causes identified in those earlier studies (GRI reports 90/0067 and 93/0115).

Figure 1 shows a layout of the gas supply and losses in a gas distribution system boundary. in this project, the main areas resulting in UAF gas losses include the following :

- Measurements: Variation of temperature and elevation/barometric pressure measurements and orifice metering inaccuracies
- Accounting: Differences in billing cycles
- Gas emissions resulting from third-party damage and line leaks
- Use by operators in the purging process and use of unmetered heaters at gate stations, - theft and tampering.

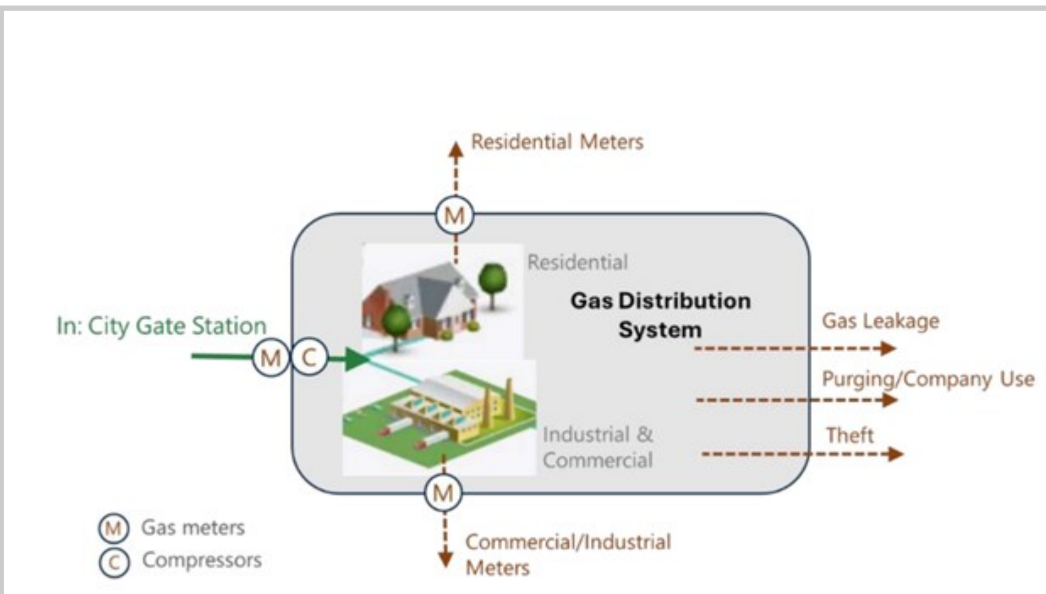

Figure 1. Gas distribution system boundary and UAF balance

Deliverables

- An interim report of data types and sources of the UAF affecting parameters.
- An interim report describing the quantification of UAF values associated with the above areas of review and recommendations for improvements.
- The results of the experiment will evaluate the bias of gas meter sets.
- A final report including the following:
    - Description of the study process, data collected, and general findings.
    - Quantification of the effects of different sources of UAF gas and identification of areas of concern or improvement.

Benefits

This study was initiated in response to the desire by gas utilities to define the contribution of gas leakage to the UAF estimates and to provide a better understanding of the causes of annual variability and to limit unaccounted losses. Estimating the contribution of gas leaks helps in reporting emissions and in directing resources to efficiently address the major causes. Additionally, more accurate estimates of gas losses result in better planning and cost saving of gas supply to meet a given demand.

Technical Concept & Approach

The project team will work on case studies involving utilities that have records of the measurement components of fugitive and vented emissions, meter reading records, and their system characteristics to include in the analysis of unaccounted-for estimates. The team is partnering with a consultant who has extensive experience in gas operations and UAF estimates.

Results

The project team held its kick-off meeting in August of 2023. During this meeting, the data collection scope was determined with the project sponsors and the contracting agreements with OTD and the consultant were put into place.

Several conference calls were held with sponsoring utilities which are considering participating in the data collection and providing records of the measurement components of the UAF gas estimates .

Status

The project started in the last quarter of 2023 and the data collection process began in January 2024. The project is scheduled to deliver a Final Report in August 2025.

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Evaluation of Viega MegaPress Fittings

The goal of this project is to evaluate Viega MegaPress fittings and validate their performance as an alternative to the traditional pipe joining methods used on meter and regulator sets, such as threaded or flanged pipe joints.

Project Description

The traditional mechanical joining method for above ground steel piping (e.g., for meter sets) uses threaded or flanged fittings. Assembly and disassembly requires "wrenching" type body mechanics and motions, which can increase the risk of injury for gas pipe technicians/fitters. Viega LLC manufactures a product called MegaPress fittings, which are crimp-style press connect metallic fittings. Plain end steel pipe is "stabbed" into the Viega MegaPress fittings, and a hydraulically powered tool is used to crimp the fittings permanently into place. The use of power tools to join piping instead of manual wrenches can reduce the risk of strain injuries and can increase worker productivity because each joint requires less time to secure.

The Viega MegaPress fittings are currently rated and approved for use on fuel gas piping, i.e., non-jurisdictional piping downstream of the gas meter. Natural gas operators are interested in finding out if these fittings can be safe alternatives to threaded and flanged fittings, and which possible standards may apply for use on jurisdictional piping upstream of the gas meter.

Deliverables

A list of possible standards that may apply to Viega fittings and their use on CFR 192 jurisdictional piping and a final report with lab test results .

Benefits

This product can reduce the ergonomic impact on front-line employees and reduce turn-around time for building meter manifolds and restoring customer gas connections.

Technical Concept & Approach

The project team is investigating applicable ANSI/ASME/ASTM standards for mechanical fittings on CFR 192 jurisdictional steel piping. Pipe test rigs using sample MegaPress mechanical fittings (sizes 1" and 2" dia.) supplied by Viega LLC will be built and lab test evaluations will be conducted including: leak testing, tensile pull-out resistance, corrosion resistance, and thermal cycling tests. Comparison testing on 1" threaded fittings and 2" flanged fittings will be conducted.

A test rig will be designed and fabricated to be used for testing the Viega MegaPress fittings at the project team facilities. This also includes the testing rigs for comparative testing, i.e. threaded fittings, flanged fittings, as well as proposed tests such as: leak testing, tensile pull-out resistance, corrosion resistance, and thermal cycling tests.

Results/Status

The project team has been focused on researching applicable standards for fittings on gas piping. Standards ANSI LC-4 and ASTM F3226 are written specifically for press-connect fittings such as Viega MegaPress fittings. The project team determined that the following F1948 tests could be potentially useful references tests for Viega MegaPress fittings: 7.2 Tensile Strength Test (ASTM D638), 7.3 Temperature Cycling/Pressure Test, 7.4 Constant Tensile Load Joint Test to be performed by an external lab.

The project team will acquire materials and design and build test rigs in Q1 & Q2 2024. The project is scheduled to be completed by The project is scheduled to be completed by Q2 2025.

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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

"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

- Cynthia Davis
Operational Quality Assurance Manager
Southwest Gas Co.

inquiries from sponsors. Since 2015, the criteria/scope of the audits changed to focus more on industry standards and utility requirements.

In average, up to 17 processes were covered at each supplier site. These included:

Management Review

Training

Analysis and Improvement

Customer processes

Equipment/Preventive Maintenance

Documentation Control

Purchasing

Engineering Change Control

Internal Audit

Corrective Action

Production

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/Status

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.

Twelve audits were performed out of fourteen in 2023. The audit reports for each audit were published in the Onspring database. Two audits were canceled due to vendor issues, and one was rescheduled for 2024. In November 2023, TECO Energy hosted a workshop to discuss the performance of audited vendors and plan for the 2024 audit cycle.

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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

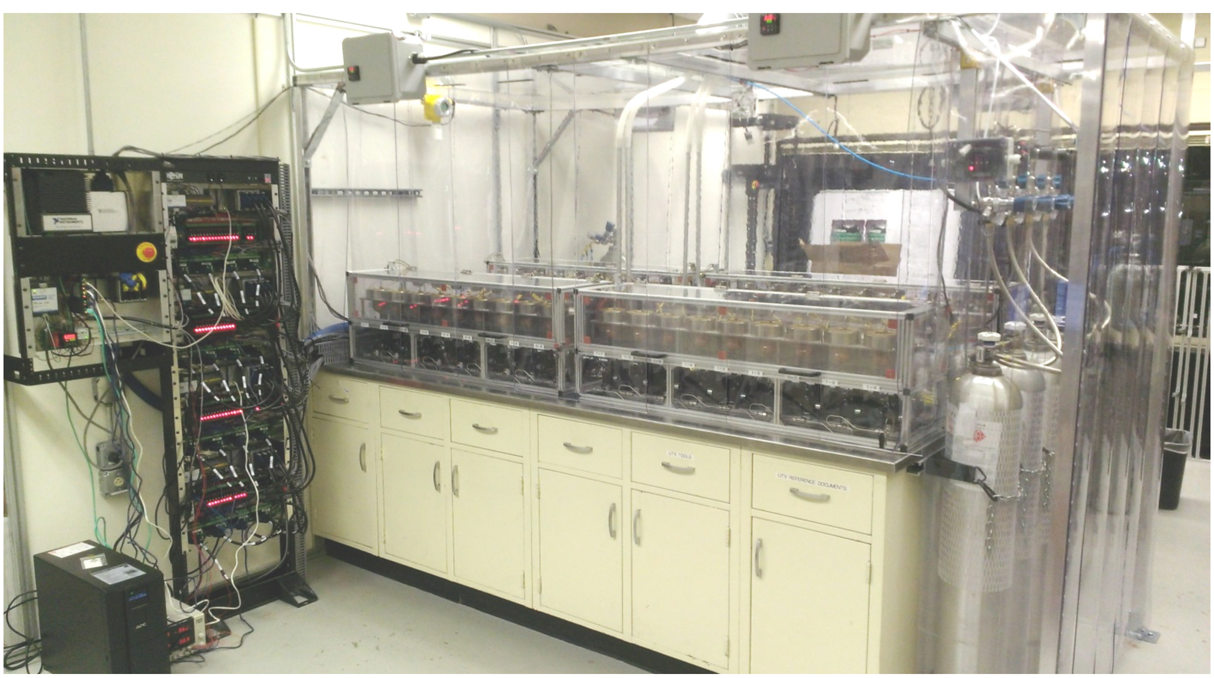
In Phase 1 of this project, which was conducted in 2014, researchers assessed the material integrity and operational compatibility of a bounded natural gas pipeline system and its components with a 5% hydrogen-blended fuel. This effort would help determine if any system upgrades might be necessary to 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.

The objective of this project is to develop a complete testing program to assess the impacts of a 5%-20% hydrogen blended fuel on metallic materials in the natural gas pipeline system. The gained information can be used to update and inform existing engineering tools to allow an integrity assessment and a safety margin determination of hydrogen blended gas use to be performed.

Deliverables

The deliverables for Phase 2 of this project include:

- Sponsor-approved hydrogen-blend use case to bound testing and engineering modeling requirements
- Prioritized pipeline materials to be tested
- Physical testing plans and design plans
- Final Report and webinar
- Detailed plan for Phase 3 to execute testing, modeling, and development of reliability and



Rig for testing with flammable gases.

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

, formulating a Design of Experiments (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/Status

As part of the project, the sponsors were surveyed about their desired use cases for hydrogen blending into the natural gas system. A concise but complete survey was constructed for the sponsors to fill out with their best or most likely candidates for such blending. A literature review was also conducted to provide an overview of the current foundational or baseline knowledge in the field of hydrogen embrittlement of pipeline steels, and individual papers of newly published research from peer-reviewed journals that have generally not made it into the foundational technical books yet. This was combined with the use cases from the sponsors and subject matter expertise to develop the design of experiments for laboratory testing.

The design of experiments (DoE) was developed with inputs and outputs for physical testing that would support the prediction in the changes in material properties of pipeline steels caused by hydrogen embrittlement. The input variable were classified as test-specific (e.g., temperature and hydrogen blend percent) and material-specific (e.g., steel grade, type, grain size, thickness, and construction/welding details). Many other material characteristics were folded into the primary material-specific categories.

The use cases submitted by the project sponsors and the results collected from the literature review were used with metallurgical subject matter expertise to refine the values and down-select/combine the levels to be tested, as well as establish a list of test methods to obtain the output results (tensile properties, toughness, fatigue resistance) that will be used to inform the engineering models that pipeline operators use for design, operation, and fitness -for-service (e.g., failure criteria by wall loss and cracking, leak vs. rupture boundary, and fatigue life).

Using the DoE, a Request for Proposal (RFP) was developed with the intention of executing the plan developed in this project.

Phase 2 of this project was completed and a final report was submitted to OTD in 2022.

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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 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.

In 2022, project partner, Ingevity, completed testing of its adsorbent material at biogas sites and indicated that they did not have a need for additional testing at the GTI Energy facilities. Ingevity expressed a willingness to share their test data with GTI Energy to advance the natural gas industry research objectives of this project. The project team met with Ingevity to plan the logistics of sharing their testing data and executed a confidential disclosure agreement to facilitate information transfer and usage. GTI Energy received a vast array of testing data from Ingevity and began to review, organize, and analyze the information prior to arranging a call with their subject matter experts to confirm understanding and support knowledge transfer.

Status

A Final Report was issued in August 2023

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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.

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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 (at the time of this project) 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 efforts led to OTD's participation on the National Fire Protection Association (NFPA) 715 committee writing of a new standard regarding fuel gas detection.

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.

Environmental test chamber

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.

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/Status

The program began with assessing the susceptibility of commercially available residential methane gas detectors to false positives from common household chemicals. It identified the two best-performing detectors. The team expanded testing to include international products, revealing strengths and deficiencies through comprehensive laboratory testing.

The next step was focused on consumer behavior. A nationwide survey of about 1,000 people revealed low awareness and ownership of residential methane detectors (RMDs), with many confusing them with carbon monoxide detectors. Recommendations were made to improve natural gas safety education.

In 2016, the team launched a pilot program installing around 1,000 detectors in homes, testing their real-world performance.

In 2018, the team recommended revising UL standards and completed testing the next tier of detectors. They recommended an alarm threshold of 10% LEL methane in air. The team also contributed to drafting a new NFPA standard for fuel gases detection. In 2019 the team developed recommendations for optimal detector placement, suggesting locations near potential leak sources like furnaces, water heaters, gas dryers, and kitchens, contrary to some manufacturer guidelines.

In 2020 the team evaluated utility gas safety literature to integrate residential methane detectors into safety messaging effectively. Findings showed utilities strongly promoted educational messages about gas safety in accordance with recommendations.

The most recent work involved a nationwide survey conducted by GTI Energy and Great Blue Research, collecting 4,500 responses.

Comparing data from 2016 and 2023, the 2023 survey included only participants with a natural gas line, contributing to higher quality data. Although detector ownership increased from 12.7% in 2016 to 29.2% in 2023, awareness decreased from 52.5% to 46.0%. Despite this, 90% of current detector owners remained interested in maintaining these devices, indicating a high perceived importance of safety. Improved placement knowledge was evident, with increased favorability for kitchens, bedrooms, and basements. Overall, while progress in ownership and placement of methane detectors has been made, further efforts are necessary to enhance awareness and adoption among consumers.

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OTD Operations Technology Development

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.

GIZMO: Gas Investigation Zone Monitor

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

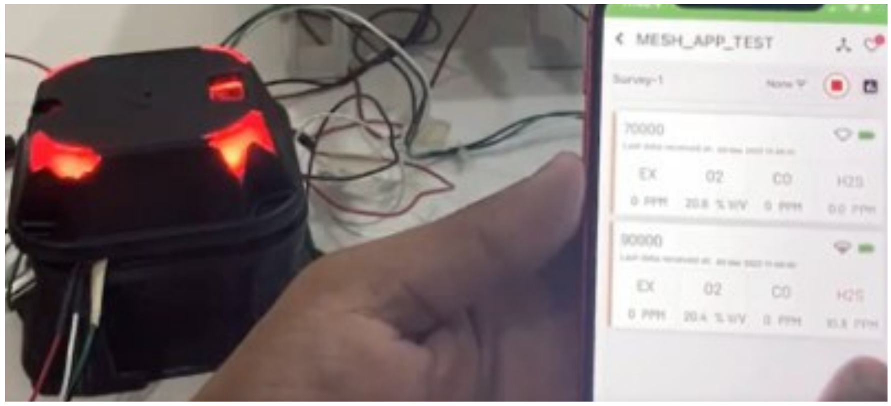
Deliverables include the development of wireless sensor nodes that can detect methane. The project team also developed mesh networking for seven sensor nodes with 100m node-to-node spacing indoors with obstructions. Each sensor node serves a webpage via WiFi that contains the data from all of the sensor nodes. This project includes demonstrations of the prototype system and a report that captures the field-demonstration data, user feedback, and needed modifications.

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.



Gizmo and mesh network app

The 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.

Results/Status

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 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. Outdoor testing was conducted on candidate methane sensors to evaluate their stability.

The latest prototype is a four-sensor gas detection system. It measures the concentrations of methane, carbon monoxide, oxygen, and hydrogen sulfide. Several of these device can form a mesh network and interact with the user through an iPhone app that connects to any other similar device nearby. The data from all these devices in the mesh network are simultaneously visible through the phone app. The mesh is self-organizing with a maximum spacing of approximated 980 feet between the devices. A “trail” of devices can be laid out to cover a leak investigation zone. Multiple phones with the viewing app can attach to the mesh to allow several investigators to view the data.

The prototype device is still in development.

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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.

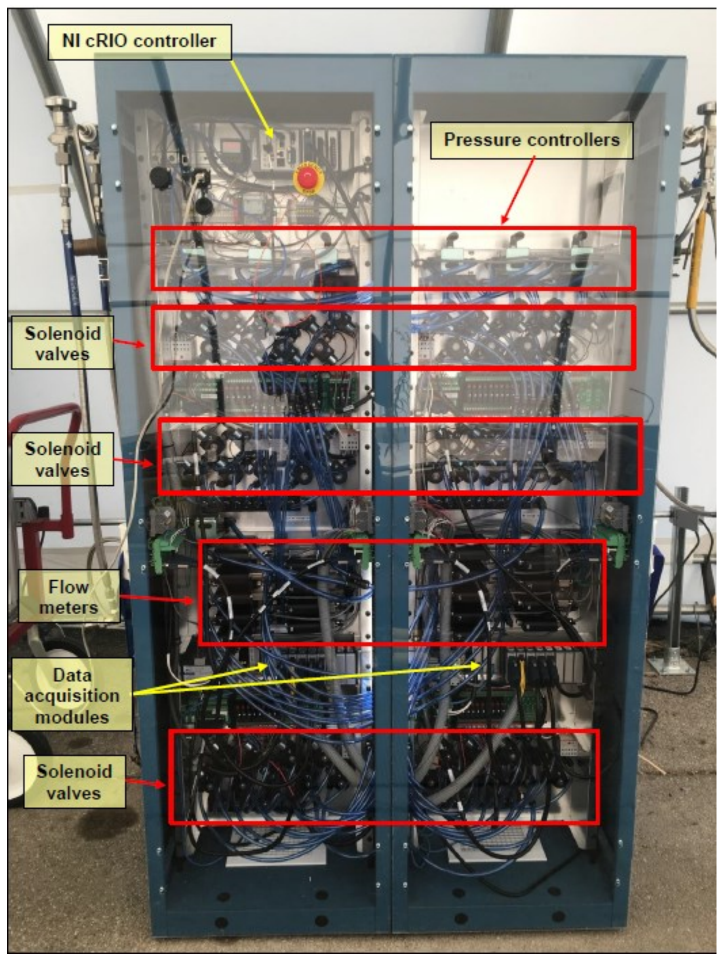
Deliverables

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.



Leak evolution test rig, instrumentation cabinet

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/Status

The testing obtained good insights into the leak behavior of Aldyl-A pipes with SCG slit cracks. It was found that leak flow varied over time and different between specimens. All samples that developed large leak rates (exceeding 10 SCFH) did so in a sudden-step manner, not a gradual rate increase. The stochastic, case-by-case nature of leak behavior may require a probabilistic analysis to predict the likelihood of a small leak reaching a large leak state within a certain time.

The lack of clear trends of leak evolution in this project’s data is likely due to the slow creep rates of polyethylene at ambient conditions. Transitioning to accelerated lifetime testing at higher temperatures may help address this issue.

Given the leak flow data obtained in this project, and with most specimens having exceeded 16,000 hours, GTI Energy recommends that the current specimens be preserved for a Phase 2 testing at elevated temperatures to accelerate leak evolution.

The forensic information gathered in this project can serve as extremely valuable input into CEC agreement PIR-23-005 “Plastic Pipeline Deficiency Inspection for Pipeline Integrity Management”, and will enable better estimation of the impact of NDE on emissions management.

A final report was submitted to OTD and the project is closed.

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Leak Repair Prioritization

Phase 3 of the project aims to advance the leak rate estimation algorithms developed in earlier phases by integrating them with advanced modeling techniques and a detailed estimation equation with a focus on improving the accuracy and applicability of these algorithms for prioritizing leak repairs, particularly non-hazardous leaks.

Project Description

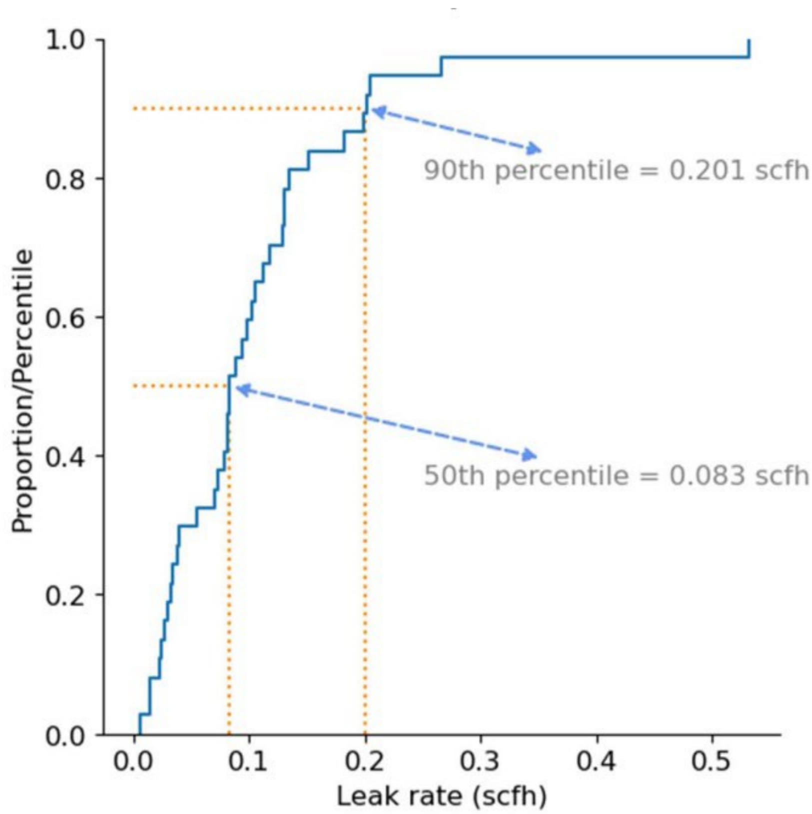
Building on the algorithms developed in Phases 1 and 2, Phase 3 seeks to enhance the estimation process by combining collected data with sophisticated modeling and an equation from UT-Arlington. This phase will involve a thorough examination of existing leak detection thresholds used by multiple sponsor companies to determine their effectiveness. The work will focus on non-hazardous leaks, specifically Grade 2 and 3 leaks, which pose minimal safety hazards but are significant from an environmental standpoint.

Deliverables

The project will deliver a refined combination of existing methods with insights from UT-Arlington's estimation equations and advanced modeling, revised emission rate conversion charts tailored for different soil types and conditions, such as barhole and pavement testing, an evaluation of the factors contributing to high attrition rates for Grade 3 leaks, a comprehensive final report detailing the findings and recommendations.

Benefits

The refined leak estimation algorithms will provide utilities with a method to prioritize leak repairs based on environmental impact. This prioritization enables more efficient reduction of system-wide methane emissions. Improved detection and quantification methods will also enhance safety and operational efficiency. By understanding and addressing the reasons for high attrition rates in Grade 3 leaks, utilities can better manage their leak repair strategies.



Cumulative distribution of emission rates of leaks with barhole to determine 50th and 90th percentile leak size

Technical Concept & Approach

Parameterize UT-Arlington Model

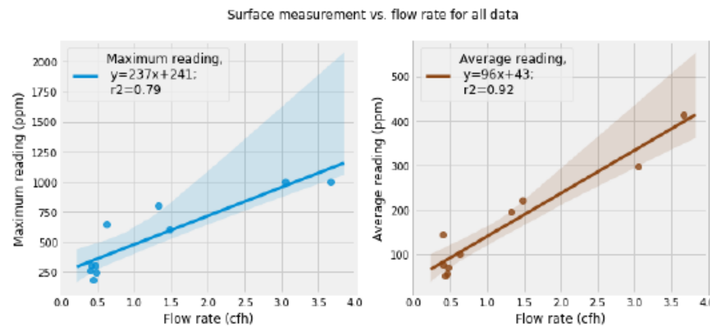
Extend the evaluation of the UT-Arlington emission rate formula by incorporating soil property estimates and their uncertainties. Collaborate with utilities to gather information on common soil conditions around leaks.

Collect Field Data

Gather data on existing Grade 2 and 3 leaks and measure emission rates from belowground leaks under various conditions. Evaluate small leaks to determine detection thresholds.

Reconcile Modeled Data with Field Data

Compare field data with estimation algorithms from both UT-Arlington and GTI Energy. Assess reasons for high attrition rates in Grade 3 leaks and evaluate the optimal differentiation points in the binning procedure for different leak types.



Surface measurement vs flow rate

Results/Status

The team developed a simplified computational model, relying on fewer measurements taken by the leak surveyor and incorporating advanced AI learning and modeling of underground physical properties. This model was tested using prior leak measurements from previous studies, yielding encouraging results.

Several implementation challenges remain before the model can be integrated into practice. These challenges include the need for an extensive database of leak measurements from a broad range of conditions and emission rates, and the development of a field-deployable smart application for leak surveyors. Although generating the necessary leak data was beyond the scope of this project, future field studies could incorporate the required measurements into a standard protocol.

Alternative simplified direct measurement techniques were discussed with sponsors, along with the limitations encountered during the study. It was decided, based on sponsor input, to conclude the project with the developed information and consider expanded scope in future projects.

The developed model offers several advantages over other estimation methods including providing a method to classify and prioritize methane leaks based on estimated leak rates, the ability to use error-prone data for calibration, requiring only three surface measurements to estimate the pdf of the leak rate, and providing a way to quantify classification uncertainty.

Possible next steps involve field testing the method, improving prior assumptions, exploring different MCMC schemes, and evaluating cloud implementation for MC simulations.

This project is complete and a final report has been issued to OTD members.

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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.

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

Delivery of one of the calibration standards ordered in 2022 for this project was delayed until May 2023.

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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

It is a common industry practice to characterize aboveground leaks as hazardous or nonhazardous using a soap test. For leaks within three feet of a building where the leak is strong enough to blow the soap off (instead of forming bubbles) the leak is classified as hazardous. If the leak forms bubbles, then the leak is classified as nonhazardous.

The goal of Phase 2 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. Originally, the scope of this project was to determine the point at which the flow rate is too large for bubbles to form. After initial tests, this scope was changed to study bubble formation at flow rates between 0.1 and 5 scfh.

Sponsors requested additional testing in order 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.

The objective for Phase 3 of this project was to perform a comparison study between soap solutions to better recognize the role of additives in bubble characterization and determine the effect of additives on bubble size and formation rate.

Deliverables

The deliverables for this project will include a final report for Phase 2, including test results, and a final report for Phase 3, detailing the impact of soap additives.

Benefits

Phase 2: 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.

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 estimates 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.

Phase 3:

Having a better understanding of the impact of different additives in soap solutions, and if they impact bubble size and formation rate, allows operators to better understand variations in results and better classify leaks.

Technical Concept & Approach

Phase 2: 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, will be performed. Three soaps and concentrations will be included in the analysis.

Prior to performing laboratory testing, a test matrix, which includes pressure variations and temperature variations (of the soap and atmosphere) will be developed. A test rig was constructed so that flow testing of a variety of different leak configurations can be simulated. The average leak rate will be determined from the testing performed. These results will be validated and compared to leak flow rates in the field. Researchers will perform probabilistic uncertainty analysis of the field-test data.

Phase 3: GTI Energy will procure soap solutions and additional equipment for testing. All suggested solutions will be reviewed for additive similarities and composition and compared with Marvelous Marianne solution used in previous GTI Energy work. All testing will be conducted in the laboratory to limit external variables. Work will prioritize the largest bubble size at controlled flow rate, variation in transitional flow rates, and temperature effects. A final report summarizing the testing and analysis will be provided to OTD.

Results/Status

Phase 2: Tests were conducted in a laboratory setting to minimize the factors that needed to be controlled when taking trials at 60 psi, 30 psi, and 7 inches water column across flow ranging from 0.003 to 10 SCFH.

Pressure does not appear to severely impact the profile of soap bubble formation at similar flow rates. Smaller flow rates (less than 0.3 SCFH) can be difficult to categorize when there are multiple ranks near that range. It can be hard to identify precise transition ranges (foam to bubbles for example). Clear determination of bins (foam, bubbles, bubbles blown off) can improve human observed classification, but may lead to overestimation of leaks.

Overall, the method displays high reproducibility at higher flow rates, and shows the potential for implementation in contexts that necessitate fast evaluation of many aboveground leaks.

Phase 3: A test plan was developed and GTI Energy obtained and tested two soap solutions. These performed relatively similarly (qualitatively) across the various tests and conditions. GTI Energy coordinated with OTD members to obtain two additional soap solutions that were not readily commercially available. For each soap solution, three sets of tests were conducted with varying pressures, flow rates and temperatures. Each set of conditions consisted of three replicates for each soap solution. Additional testing was also done on all four soap solutions to observe bubble formation in the transition stages at and between different leak category flow rate ranges, based on the leak categories and soap bubble formation descriptions provided in Phase 1 of this project.

A final report for Phase 2 was presented to OTD in 2022. In 2024, GTI Energy will work to complete testing for Phase 3 and draft a final report.

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Drone-Based Methane Detection

Researchers conducted field testing using UAV mounted methane detection technology to perform emergency surveys in response to natural disasters and developed SOP documentation for deploying UAV based technologies for emergency survey.

Project Description

Unmanned aerial vehicles (UAV, drones) have been proven capable of identifying natural gas leaks under specific conditions (e.g., large enough leak, able to fly the drone through the leak). The objective of 7.18.d Drone Based Methane Detection Phase 2 is to establish specific recommended best practices with standard operating procedures (SOPs) to use UAVs under emergency conditions created during a natural disaster such as a hurricane, tornado, or landslide. These recommended practices will cover every aspect of the use case including preparation prior to the natural disaster, staging in the immediate aftermath, and deployment of the technology to locate large leaks quickly in areas that cannot be easily accessed. The purpose of using a UAV under these conditions is to scan a large area quickly identify any large hazardous leaks. If no leaks are found the local distribution company (LDC) can potentially avoid shutting off the gas supply to a large area.

Deliverables

The project deliverables for Phase 2 include field testing data from drone flights, Recommended Best Practices and an SOP document on using UAV mounted methane sensors under emergency scenarios created by natural disasters such as hurricanes, tornados, or floods.

Benefits

UAVs with the capability to detect methane can serve as vital tool for natural gas companies by providing a more efficient, cost-effective, and safer way to perform to identify leaks under natural disaster conditions. In these scenarios, fallen trees or landslides can block access to large areas. Deployment of UAVs provides an option to explore these difficult to access areas and identify natural gas leaks that could prove hazardous. During these natural disasters houses can be destroyed, which can cause gas to escape through open piping.

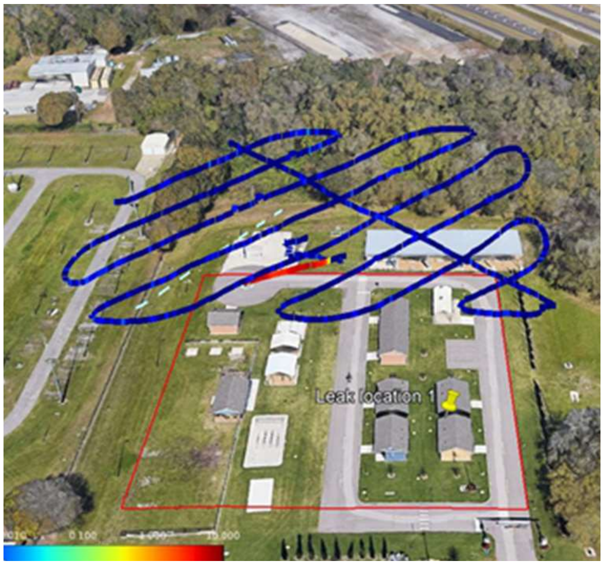
Technical Concept & Approach

Field Testing

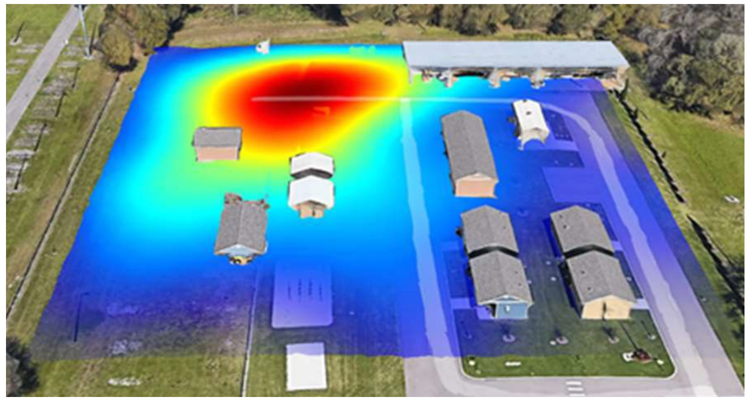
Conduct field tests which are to include many flights under identical conditions in a focused and repeatable manner to get an in-depth understanding of the factors that drive false negatives (missed leaks) and false positives (identification of leaks that are not there) for the natural disaster use case. Use data collected during field testing to create the recommended best practices and/or SOPs for the targeted use in response to natural disasters.

Development of Recommended Best Practices and/or SOP Document

Develop the recommended best practices and/or SOP documents in a manner which ensures that an LDC can be prepared to deploy UAVs in response to a natural disaster. Several factors must be considered when deploying UAVs under these conditions. Preparation before a natural disaster hits can alleviate many potential hurdles that can arise after a natural disaster has occurred.



Grid search patten is used to survey a wide area. Grid density (distance between paths) and altitude were varied as part of the study.



The Methane heat map formed from measured methane readings captured by the ABB HoverGuard UAV shows how the plume forms both in width and height.

Results/Status

This project evaluated the possibility of using UAVs for conducting emergency leak surveys specifically to clear a wide area of major line breaks during a natural disaster. Leak flow rates of greater than 30cfh were tested with two alternative methane sensor methods: downward scanning laser, and a high sensitivity (ppb) point sensor. Both methods showed the feasibility of conducting wide area emergency leak surveys.

The team's testing established that detection of large leaks was feasible when flying at high enough altitude to allow for automated grid search patterns and a wide area could be surveyed quickly with sufficient search grid density and speed of flight. Wind conditions varied how far downwind the plume will be detected, which is more of a concern for a point sensor that needs to fly through the plume, but identification of the general location would still be established to guide further investigation.

The team also developed a list of considerations that LDCs should consider for deployment of UAV based emergency leak survey. LDCs should consider: if there will be a dedicated in-house team or if they will have to rely on outside service providers, how to coordinate this leak survey with other emergency response activities and agencies, what type of disasters are common within the LDC's system, and if they would benefit from creating search areas using GIS information to port into the UAV's flight mission.

A final report was submitted to OTD and the project is closed.

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OTD Operations Technology Development

Reserve Strain Capacity Determination

A field demonstration of advanced stationary continuous methane-monitoring systems is was completed. Researchers evaluated the tools for potential use at a variety of gas facilities.

Project Description

In this project, a research team evaluated and demonstrated 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 involved field demonstrations of commercially available systems as well as 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 on the performance of continuous-monitoring systems will help gas utilities choose the correct instruments for specific sites and situations, potentially be more proactive in identifying leak indications, reduce releases to atmosphere, and, in some cases, provide readings of higher resolution than conventional hand-held leak detection tools.

Technical Concept & Approach

A protocol was developed for the necessary metrics needed to evaluate leak-detection instruments from four different vendors 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. Researchers gathered user requirements from the perspective of analysts, controllers, site operators, and leak-survey engineers. Understanding how these users interact with their instrumentation and resulting data aided in the selection of instruments that met 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 be able to meet regulatory requirements going forward. Leak-detection instruments are a critical part a robust pipeline leak-detection program, as recommended in the American Petroleum Institute (API) recommended practice (RP) 1175.

Results/Status

The continuous methane monitoring instruments were installed at the site in May 2019. Controlled-release testing was performed on site to verify instrument performance and accuracy. Additional controlled releases were 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 enabled larger flow rates.

Prior to the beginning testing, 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. After the installation of sensors, conference calls were held with each instrument provider to design data-management, data-storage, and data-visualization procedures. The controlled releases were conducted for roughly 10 minutes per release rate setting to allow time for the instruments to detect the gas plumes. A total controlled release test required roughly 60 minutes.

The initial survey did not find any pre-existing leaks at the station. Over the site observation period, fluctuations were seen in the methane levels due to intentional controlled releases, maintenance that caused releases, and a few minor leaks that developed. The data was initially analyzed using "wind rose" distributions that correlated methane emissions observed versus wind direction. This analysis was refined to include wind speed, in addition to direction, to the distribution.

The four instruments initially in the study reported on varying time intervals. All four data sets were normalized to one-minute intervals to allow comparison. The average concentration over each minute of data was calculated and retained. Using this data helped understand the baseline values of methane emission and fluctuations in these emissions. The cumulative data can be used to determine reasonable alarm thresholds for the instruments to prevent an excessive number of false positives.

An analysis was performed each month on the instruments' leak-detection performance during controlled releases. Additionally leak indications identified by the instruments as well as concentration statistics were summarized in the monthly reports. Monthly reports contain visualization of instrument methane concentration as a function of wind direction and speed.

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 an improved interface and the availability of 4G cellular hardware for integration.

Eighteen months of continuous sensor deployment demonstrated each sensor's capability to be installed for long-term leak detection applications. Meteorological instruments generally functioned well, though it was identified (by downloading concentration data) that one device did not gather wind data. In addition, all sensors displayed robustness in both solar panels and battery systems with only one minor power-related issue encountered.

All 4 sensors successfully gathered data and allowed the data to be accessible by the operator electronically. The project found that the sensors can reliably detect natural gas releases which are greater than 10 cfh within 10 minutes.

This project is complete and a final report has been issued to OTD members.

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Advanced Leak Detection Technology for Grading Leaks

Researchers will explore existing leak grading procedures, how thoroughly the procedures perform, and whether those procedures could include additional or different technologies with a specific focus on the open path laser spectroscopy (OPLS) detection method, which could reduce costs associated with leak surveying.

Project Description

The goal for this project was to investigate leak detection and quantification devices to determine if surface concentration measurements can be reliable predictors of surface expression flow rates from underground leaks. The project team gathered and evaluated information about current leak grading methodologies to better understand how these instruments can be used in this application, followed by field testing and data analysis. Pacific Gas & Electric (PG&E) were partners in this effort, providing sites and personnel to facilitate testing.

The project was initially focused on the RKI Instruments' device which uses an open path laser spectroscopy (OPLS) detection method, though other instruments were added as the project evolved. Field testing was expanded to include additional leak detection instruments.

DP-IR, walking probe (black), bar hole probe (clear);

Deliverables

Key deliverables included development and execution of a field-testing program to evaluate instrument performance, to investigate if surface concentration measurements can be reliable predictors of surface expression flow rates from underground leaks for the purpose of leak grading.

Benefits

This project explored options for open-path instruments to be used either instead of or in conjunction with widely used technologies such as combustible gas indicator (CGI), flame ionization detector (FID), or DetectoPak Infrared (DPIR). Open-path sensors can more quickly examine large areas for leaks thus reducing labor costs and potentially increasing the overall efficiency of leak surveying. With proper data validation these same instruments may also be used in a combined capacity to also grade leaks.

Most leak grading standards are based on the Gas Piping and Technology Committee (GPTC) standards which tend to be based solely on pump-based instruments that measure subsurface gas concentrations. The industry will benefit from an evaluation of existing protocols and recommendations for the potential use of leak detection technologies.

Technical Concept & Approach

Evaluation of Current Methodologies

Building upon the work of Phase 1, this project garnered sponsor input to better understand leak grading procedures, and consider other, more widely -used instruments in addition to the OPLS. The instruments used in this work featured multiple technologies: open cavity (OPLS), pumped closed cell (DP-IR), open path laser (RMLD-CS), and a Hi-Flow 2 with an enclosure method. field testing gathered data including measurements of surface concentrations and flow rates.

Field Testing

Field testing was conducted in July 2023 with PG&E, at their training facility and in their service area. The project team collaborated with researchers within PG&E's R&D department who had extensive experience working with RKI Instruments' OPLS device. The test design was adjusted to have more focus on surface expression measurements compared across a range of devices – with the RKI Instruments' OPLS device being of primary importance. The three other devices under testing would be benchmarked against flow rate estimations attained by the Hi-Flow 2.

Data Analysis and Reporting

Correlations were drawn by performing linear regressions on the concentration data (either in ppm or path-integrated ppm-m units) when compared to the flow rate in units of standard cubic feet per hour (scfh). Overall, this approach, using measurements at or just above ground surface, did not appear to yield reliable predictions of surface expression leak flow rate, although there were informative elements of the data. There are multiple factors affecting the results that are inherent to uncontrollable variables in leak surveying and quantification generally. Key factors that likely influenced data collection and results are discussed in the final report.

Results/Status

The instruments used in this work featured multiple technologies: open cavity (OPLS), pumped closed cell (DP-IR), open path laser (RMLD-CS), and a Hi-Flow 2 with an enclosure method.

Some correlations were found between concentration measurements (on a logarithmic scale) and surface expression flow rate. While gas concentration expressed at the at or near surface is proportional to flow rate expressed at the surface, the information obtained in this manner is not sufficient grading.

The data did show that there is a limited but encouraging correlation between surface concentrations obtained using survey instruments and surface expression flow rate. However, these results are limited by the small sample size and low

Taking surface concentration measurements.

flow rates (scfh < 1). This resulted in a few outlier measurements which significantly affected the correlation results. The outliers resulted from leaks that were larger in spread with multiple "hot spots" of high concentration.

It is known that leak detection is not simply a function of instrument quality (accuracy, precision, and quantification limits). Subsurface conditions, the depth at which a leak originates, and the gas composition itself greatly impact the surface expression of plumes irrespective of the technology used to detect it. These complexities further render the proposition of leak grading with this approach more difficult.

It seems feasible to incorporate surface expressions measurements to aid in estimating surface expression flow rate for environmental impact, if not for grading and repair prioritization purposes. Further development would require a larger sample size and a wider variety of flow rates and conditions (of unknown scope) to be more consistent, and still may not produce reliable results. These findings are not strong enough to warrant or suggest further development at this time but may help inform other work in this area.

This project is complete and a final report has been issued to OTD members.

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OTD Operations Technology Development

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 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 a final report documenting the findings from a workshop, a roadmap, and a 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 been injected into natural gas pipelines, hydrogen can have unique 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/Status

To initiate the discussion and determine the focus of related OTD projects, a workshop was held in July 2020 where different approaches were presented to the group and the concerns of the sponsors around safety, operations and impacts to components were collected.

The team organized a series of meetings to better define the issues identified in the workshop and create a list of projects to be proposed to OTD. This set of projects were prioritized to have the most pressing issues investigated first. A set of OTD projects were presented in various rounds of funding.

The team also developed a hydrogen information site. This site is designed to host fundamental references related to operations, safety, end use, environmental impacts, codes, standards and materials compatibility. It is a place where users can perform a search a quickly narrow it down to the references of interest and serves as a one-stop point to establish, for example, whether there are ongoing efforts already investigating concerns from sponsors.

This project is complete and a final report has been issued to OTD members.

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Project No. 7.20.a

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

Deliverables include deployment and testing of improved prototype on utility sites.

Sensors on pipe and in soil.

Benefits

The anticipated benefits include real-time information on events before they develop into incidents, allowing pro-active response to developing situations such as construction activity near the ROW that has not yet infringed on the pipeline.

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

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.

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 aboveground 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.

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.

Results/Status

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.

Multiple hardware improvements were made both in the sensors and in the methods of installation. The firmware algorithms to process the vibration sensor signals were developed and tested to replace third-party equipment used during the earlier work.

Data management and visualization tools were upgraded. The original system used multiple Esri ArcGIS tools for visualization. The data available was limited by the bandwidth of the RPMA radio system. The shift to LTE-M provided much more robust communications with the sensor endpoints.

As of 2023, one new test site has been commissioned and one station at the original test site was upgraded. These sites are generating test data that can be viewed with a user dashboard. The original sensor functionality is preserved, the vibration sensing is improved, and additional sensor types are in place.

A final report was issued in 2023 and the project was closed out

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Operations Technology Development

PSI Laser QGI Field Testing Phase 2

Researchers will evaluate advanced proto-types of the Remote Methane Leak Detector - Quantitative Gas Imager (RMLD-QGI) developed by Physical Sciences Inc. (PSI) which could significantly reduce the cost of Optical Gas Imaging for methane leak inspections.

Project Description

This project will evaluate advanced prototypes of the Remote Methane Leak Detector - Quantitative Gas Imager (RMLD-QGI) developed by Physical Sciences Inc. (PSI). Collaborating with Heath Consultants Inc. (Heath), GTI Energy (GTI), and OTD members, this project will support demonstration testing to evaluate performance of the advanced prototype QGI. Performance evaluation and feedback will be obtained though use of the QGI in real-world settings of distribution system leak surveys. The project's ultimate goal is to complete rigorous validation tests demonstrating that this technology: a) is convenient to use in real-world downstream municipal leak survey operations as well as upstream Leak Detection and Repair (LDAR); b) meets stated performance specifications; and c) can be used to both find and prioritize leak repair.

The first project Phase was completed and validated performance at the GTI laboratory (Figure 1). The QGI demonstrated its ability to survey, image and quantify natural gas leaks at meter sets. The technology was also demonstrated at compressor vents and underground leaks. The second project Phase proposed here will validate performance at real-world sites, improve the concept of operation for ground leaks, and obtain end-user feedback to further improve the technology.

In a parallel NIOSH (National Institute of Occupational Safety and Health) Phase 2 SBIR (Small Business Innovation Research) program effort, the overall system was miniaturized to a handheld unit with software and firmware optimized for stand-alone operation. The operating techniques and algorithms for deducing methane flux (i.e., emission rates), and emission sources were advanced and optimized using the controlled field test data.

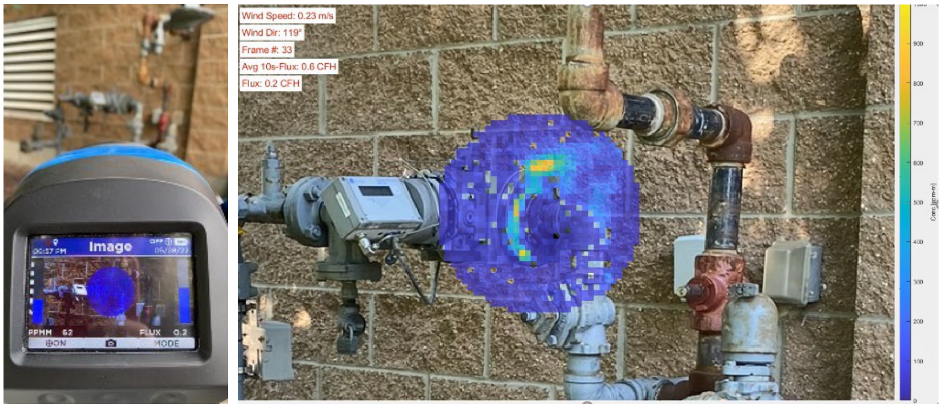
The QGI provides the user images of the background scene overlaid with two-dimensional spatio-temporal maps of path-integrated methane concentration versus position. It is capable of gathering these images from distances (50-100 feet) safely away from the source of the plume. Knowing the local air speed and direction, the tool estimates methane emission rates and path-integrated concentrations. For LDCs, the use case will be offering a relatively quick method to roughly estimate leak size to inform leak repair prioritization efforts.

Deliverables

Along with a final report, deliverables for this project include a final conference/webinar to review the results of this phase of the program and detail the next Phase for commercialization and implementation.

Benefits

A 2013 study prepared by the office of US Senator Edward Markey, summarizes the national impact of natural gas leakage. Most of the ~250 billion cubic feet of annual leakage volume originates at a relatively few large leak sites. Identifying and repairing those leaks is expected to mitigate approximately 90% of the loss, worth about $2B. 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. Quantitative Gas Imaging provides emission rate at each inspection site, enabling prioritizing the severity of the leak for



Snapshot of meter set showing a gas leak.

repair. This allows the operating companies to focus their repairs on larger leaks.

There is potential for QGI to reduce costs and training time due to its relative ease of operation.

Technical Concept & Approach

The primary tasks for this project include:

QGI Instrument Readiness

Prepare the advanced prototype(s) for field testing. Preparations will include system calibration, and bench testing. System calibration includes laser operating parameters setup, system parameters setup, optical alignments, and two-point measurement calibrations. Bench testing includes system noise characterization, user interface operational testing, and controlled release tests for verifying measurement performance and display of instrument features and functions.

Simulated Real-World Municipal Leak Testing

Develop test plans for conducting simulated real-world municipal leak surveys. Each end-user may have a unique test plan adapted to their locations and survey procedures. QGI performance will be documented. End-users will be trained in operating the QGI, and feedback will be collected to improve the QGI product.

The subtasks include:

- Define test plans that include test locations, duration of tests, and test dates.
- Devise a routine to train end-users in the operation of the QGI.
- Compose and implement an end-user questionnaire to collect feedback on the training, handling, operation, and reporting features of QGI.
- sequential field tests at 3 or more selected municipal survey areas or testing facilities meant to emulate real-world conditions.
- Analyze field test data and summarize the findings. Based on user feedback, include minor QGI modifications and updates between sequential tests.

GTI will conduct direct flux measurements of a subset of the leaks to compare with the QGI method.

Results/Status

Initial trials with the instrument at a test facility will begin in May 2024, followed by additional testing with a project sponsor in June 2024. Other sponsors have expressed interest in hosting field trials, and the planning is ongoing.

PSI is currently updating software and preparing the QGI instrument for field study. Additional calibration and preparation will be made as host sites and timelines are confirmed. This work will continue until field testing approaches.

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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 methane leak detection and monitoring from the natural gas pipeline system has driven recent technology development and applications, specifically using remote-sensing instruments on unmanned aerial vehicles (UAV). UAVs 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 and differing 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 the test framework to field validate drone-mounted integrity and methane detection sensors, and information from an evaluation of uncertainty.

Benefits

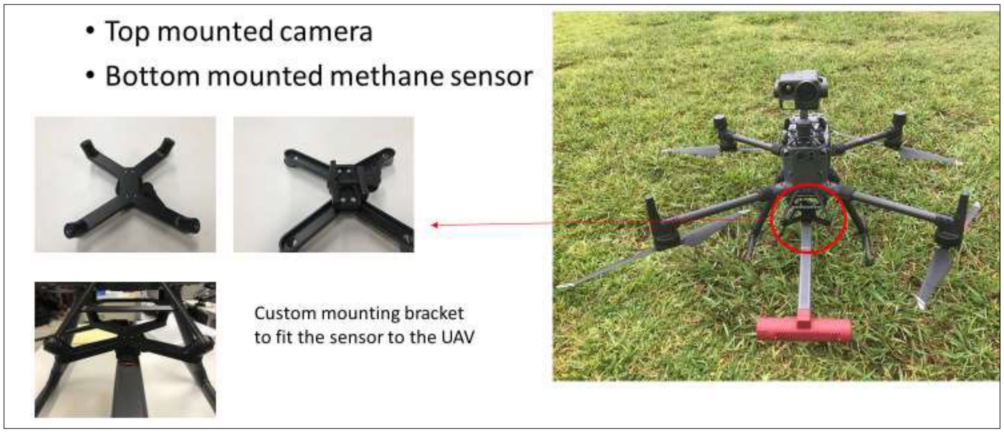
Use of the advanced detection technologies for natural gas leak detection can aid in reducing risks associated with undetected natural gas leaks and overall environmental impacts created by methane.

There is a unique co-benefit to leak sensing technologies mounted ondrones, 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 supports the further validation and adoption of new leak-detection technologies by obtaining a clearer understanding of uncertainties surrounding deployment of sensors at operating facilities.

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 on performance testing on the methods used (rather than individual sensors), it is possible to achieve a more effective and standardized framework for validation.



Camera and Methane Sensor Drone Mounting Configuration

For this project, the research team worked with 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 conducted real-world validation of sensors with long-term performance tests of remote leak-monitoring technologies at remote/rural metering and regulating stations.

Results/Status

The main goal of the project was to advance and validate drone mounted remote sensing technologies at sites representative of the real-world. This was accomplished via development of the SeekOps drone system and whole system evaluation methods. The team demonstrated that the receiver operating curves (ROC) and area under curve (AUC) statistics were useful for comparing the performance of the system across various test scenarios making them an effective method to “grade” or evaluate system performance.

The SeekOps drone technology showed promise for detecting belowground natural gas transmission pipeline leaks across the range of leak rates studied (0 – 45 scfh). To be most effective it is recommended that the drone make multiple passes across the area being surveyed and fly in a box pattern around the around being surveyed. In addition, the University of Dayton integrity threat monitoring software showed promise for being able to locate potential integrity threats among a crowded landscape at METEC. This indicates that given the time to allow the system to train on various images of potential integrity threats (e.g., heavy equipment, field trucks, people) the system could progress into something quite useful.

Operators may also consider the impact of fog and reviewing existing survey procedures when deploying drone surveys. This project is complete and a final report has been issued to OTD members.

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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.

Deliverables

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 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.

RAMFAN Blower

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/Status

The team contracted with Fire & Risk Alliance LLC (FRA) to design and perform the testing using both a built structure and computational fluid dynamic (CFD) modeling. The three main tasks included characterization of the selected blower, initial testing to look at the position of the blower, and final testing to determine the impact of selected positional and structural variables on leaking methane gas. The built structure was a residential test home with external dimensions measuring nominally 20' x 40' x 20' that was constructed of dimensional lumber to simulate a multi-level residential structure. The team selected a RAMFAN Turboforce Ventilator LB6201 for evaluation.

Initial tests were made to differentiate the impact from negative pressure (fan blowing out of the building) and positive pressure (fan blowing into the building). Elevation of the fan and angle of flow with respect to the plane of the floor were also examined. It was found that secondary openings had a high impact on the rate of ventilation. The blower also provided the best ventilation when positioned inside and blowing out but this was not deemed practical


FRA Custom Built Home for Gas Dispersion Studies

because it would force first responders to enter the building. Elevating and angling the blower did not offer any improvement in ventilation but continued to be investigated in case actual methane gas testing gave different results.

The team conducted a series of 7 test sequences investigated 31 different ventilation configurations. Testing showed that the most effective and most easily applied solution was to position the explosion proof fan four feet from the building entrance blowing into the building. Secondary openings had the most influence on improving ventilation performance, especially for smaller floor plans. Active HVAC negatively impacted the efficiency of ventilation by re-circulating and distributing the gas while working against the air flow of the ventilation. It is recommended to cut off power to a facility with an expected leak. Full results are available in the final report.

This project is complete and a final report has been shared with OTD members.

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Project No. 7.20.f

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.

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.

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.

Deliverables

This project will deliver a means to quantify volumetric quantities of methane emissions produced from a pipeline purge.

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 from this previously untracked source in the future.

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.

Results/Status

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.

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.

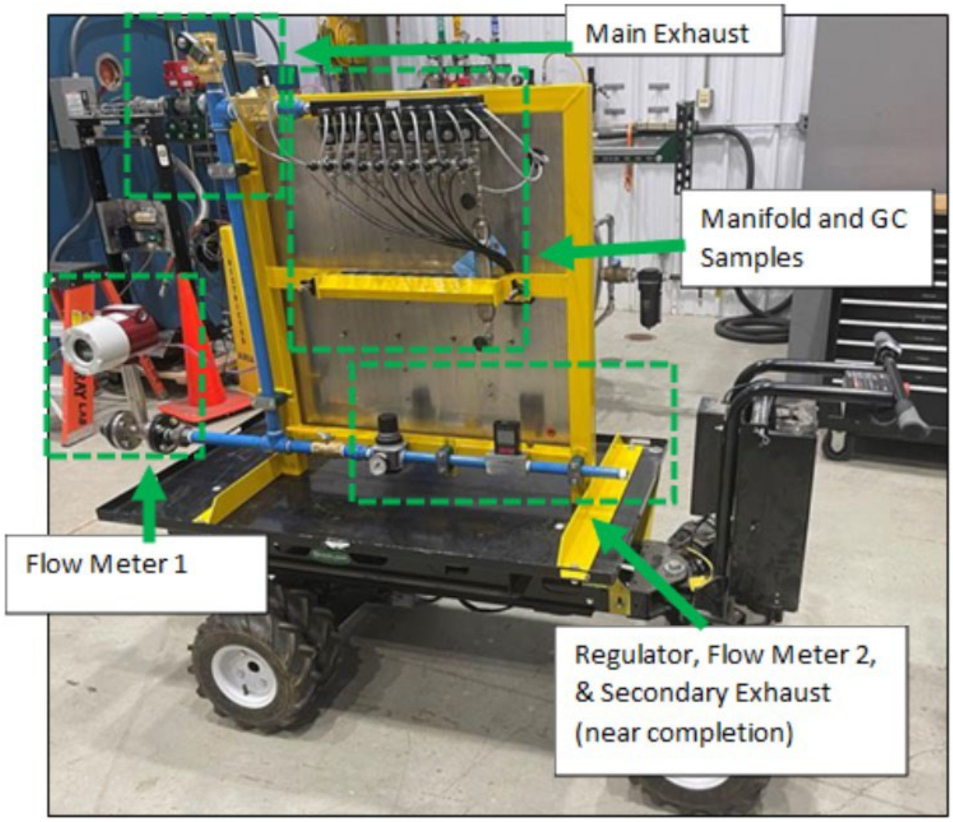
With this general framework, the team has three possible paths to design the purge flow meter:

Indirect Hydrocarbon Measurement

This design requires 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.

Direct Measurement of Hydrocarbons

This approach involves diverting 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.



Finalized Testing Rig

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.

In 2023, project sponsors approved an enhanced test design that would reinforce the evaluation of the emissions profile for the outlined project objective. This enhanced evaluation would use cylinders run through gas chromatography analysis to isolate specific times along the testing process. In Q2 of 2023, more materials were purchased to aid in the construction of the testing rig which included a static in-line gas mixer to better homogenize the measurement streams across two purge exhausts and potentially aid in purge efficiency. The testing rig was further enhanced with brackets to support the main flow meter needed for testing with an exhaust installed, as well as other weathering improvements to allow for outdoor use.

The testing rig has been finalized, and the test scenarios outlined were refined to define three scenarios that will be compared to the first planned scenario (a traditional purge evaluation) and observe any efficiencies gained by adding an-inline mixer.

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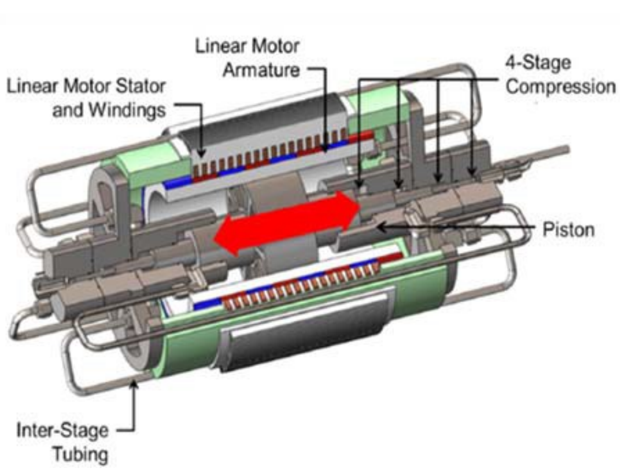
Methane Mitigation Using Linear Motor Leak Recovery Compressor

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 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.



Early conceptual rendering of a Linear Motor Compressor

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.

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.

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/Status

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 stand-alone business operation. Several product scenarios were considered.

In the 4th quarter of 2023, the team finalized the design of the compressor stages, including the valves and pistons that needed to be resized to balance the flow and pressure ratios across each stage. In addition, the team has worked to assemble and install the control hardware at the test site that will provide power to the compressor.

The project team has continued to finalize and order fabricated components that will be used to assemble the leak recovery compressor as progress towards the demonstrations continues.

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Project No. 7.20.m

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 decarbonization. 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 "Evaluation of Residential Methane Detectors", 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.

Hydrogen Sensor

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.

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.

Test Chamber

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.

The final test set will determine the point at which each detector begins to alarm with each gas blend.

Results/Status

Seven different models of residential methane detectors from six brands were tested with at least five devices from each model, with exposures being performed in quadruplicate. The models used were Kidde, Universal, New Cosmos, Honeywell, Primatech [m], Primatech [d], and First Alert. The models in these brands can detect both explosive gas and CO except for Primatech [m], New Cosmos, and Honeywell. The data recorded was a determination of pass or fail dependent on if the device made an audible alarm and if the CO sensor triggered. The following four tests were performed on the detectors:

Test 1: Verification of each detector's response to methane in air at 25% and 10% LEL. **Test 2:** Testing for hydrogen impact on detector response at two % LEL levels (10% and 25%) with four test gases containing varying amounts of hydrogen. The test gases were diluted to reflect % LEL levels of methane only, irrespective of the presence of hydrogen. **Test 3:** Testing for hydrogen impact on detector response at two % LEL levels (10% and 25%) with four test gases containing varying amounts of hydrogen. The test gases were diluted to reflect total % LEL including hydrogen. **Test 4:** Estimate the relative responsiveness of each detector. The hydrogen blend test gases used were: 5% hydrogen in methane, 10% hydrogen in methane, 15% hydrogen in methane, and 20% hydrogen in methane.

The verification tests confirmed that all tested RMDs responded to methane at 25% LEL in air with an audible alarm. At 10% LEL methane in air, most alarms responded consistently, but some had only a 25% success rate and others did not alarm at all. The final Test 4 is an estimation of detector responsiveness, ranking each device from one to ten (best to worst).

Hydrogen blended methane gas did have an impact on detectors from some manufacturers, but only on the CO sensor. False alarms indicating CO were produced at multiple %LEL levels, especially at 10% LEL even when the gas alarm also sounded. RMDs with both gas and CO sensors may not be the best selection for natural gas blended with hydrogen, especially if the alarm threshold is at the desirable 10% LEL level. The single gas sensor detectors performed the best in this study.

The interference of hydrogen on electrochemical CO sensors is a known phenomenon. Interference from other gases is one of the chief limitations of substance-specific electrochemical sensors. Many CO sensors have an internal activated carbon filter that is meant to remove hydrogen sulfide and other similar acidic gas interferents before they can activate the CO sensor inside. However, this may be insufficient in dealing with high hydrogen concentrations because hydrogen is generated in the first part of the CO detection reaction which complicates and adds to the false positive alarm issue. Further testing is needed to quantify the concern.

This project is complete and a final report has been shared with OTD members.

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Project No. 7.21.a

Evaluation of Advanced Technology for Investigating a Gas-Filled Structure

Researchers are exploring the applicability of advanced technologies such as hand-held 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 the impact of different window types on detection capabilities of handheld laser methane detectors and optical gas-imaging cameras, and the locations of other detection points (such as eaves or vents) on the structure where technologies can be used. Other factors that may also limit performance of advanced technologies, such as distance, wind speed, wind direction, and obstructions.

The goal of this 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

Deliverables for this project will include a public white paper/fact sheet detailing the use of handheld laser methane detectors and optical gas imaging in a gas-filled occupancy scenario, another public white paper/fact sheet detailing the use of robots for a gas-filled occupancy scenario, and a final report.

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

Development and Testing Framework

Work with the robot company who manufactured the robot to advance gas detection capabilities. This may include upgrades to the mechanical functions of the robot to improve roving aspects. Integration of methane detection devices will also be considered.

Assess the effectiveness of the laser point and shoot devices in penetrating windows for leak investigation. This will include lab facility testing to explore the impacts of different windows types and coatings.

Testing at a Utility Owned Leak Training Facility

Condict 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.

Testing During First Responder Training

Validate the lab based and leak training facility testing with responder personnel and collect feedback on how technologies may be utilized and integrated into current procedures.

Analysis and Evaluation

Review and analyze data collected during the leak training facility and first responder training testing. Develop recommendations on the use, integration, and further evaluation of these technologies.

Results/Status

For this project, the team conducted laboratory-based testing of the technologies using different window types and films affixed to glass, field-based testing at a project sponsor leak training facility, and onsite support of sponsor field personnel participating in emergency preparedness exercises.

The testing that was conducted confirmed many suspicions regarding the viability of measurements through energy efficient windows that are made with low-e glass. There is no single method that would allow for a consistent reading of the inside of the building behind the window. The angle or duration of measurement alone cannot be configured in a way where any results can be the sole determinant for a gas-filled structure. A laser methane detection device still holds a lot of utility when used as a first step in determining the presence of a leak but should not be the only method that is used. That lesson can be even further amplified when the path of the laser is obstructed by a window with a relatively low solar heat gain coefficient (<.5).

Tactical robot in preparation to climb stairs of building

Unfortunately, due to supply chain shortages impacting window availability and delivery, testing had to be managed using window films affixed to glass. Despite this modified approach, the team still believes the safest recommendation is to pair a laser methane detection device with a tactical robot or some other advanced technology. By leveraging a multiple tool approach, results from any single technology may be confirmed and validated. Using multiple devices that aid each other in detection is likely the best way to certify from a safe distance whether or not an enclosure has become gas-filled.

Organizations would benefit from developing specific training programs geared towards best practices for laser device usage and building clearing procedures. Detailed procedures and training will be critical for field personnel and other first responders.

Feedback from the operators indicated that there was clear benefit to using laser-based devices to scan and clear rooms. Speed of scanning and the ability to search difficult to access areas, especially along the ceiling line, were cited as primary benefits.

This project is complete and a final report has been shared with OTD members.

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Project No. 7.21.b

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

urrently, 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.

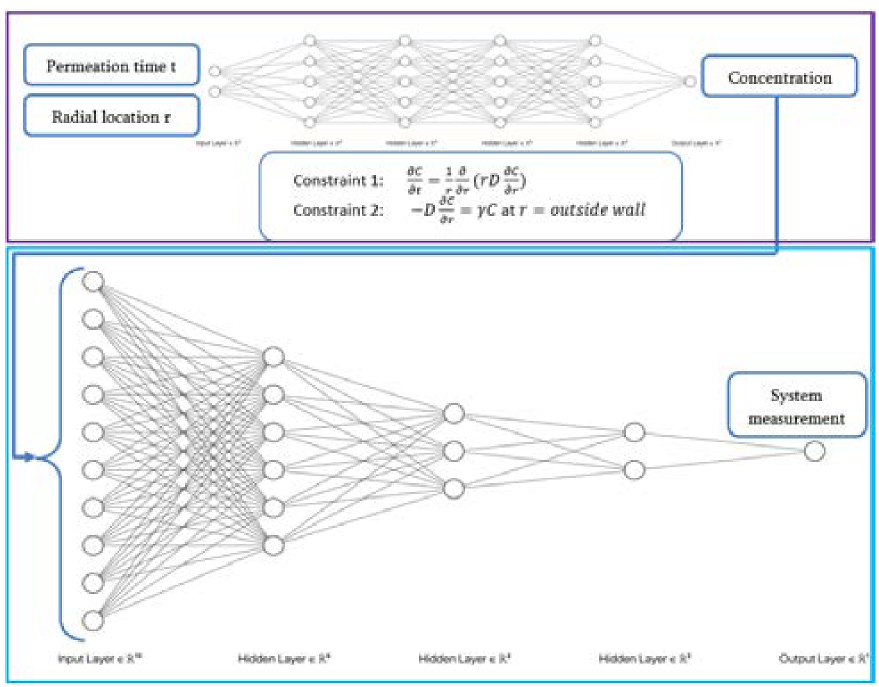
Deliverables

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.



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/Status

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.

The project scope needs to be reviewed with the sponsors and adjusted. It was determined over time that there are several parallel efforts in this space; the review is to assure there is no duplicative effort. The review meeting was scheduled for January of 2024.

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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 detect leaks and provide accurate 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.

A variety of instruments are being evaluated.

Deliverables

A Final Report will summarize results of this project.

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 are capable of hydrogen analysis; however, historically these have not been utilized by the industry at custody transfer sites. A better understanding of the impacts of hydrogen and which technologies can be leveraged for this monitoring will help operators safely integrate hydrogen within their networks.

Technical Concept & Approach

A review of instrumentation evaluated, and their 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 "Online Biomethane Gas Quality Monitoring" and 7.16.g "Online Siloxane Detector Testing").

Results/Status

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 detailed comparison of four GC technologies was developed, and sponsors were given an opportunity to provide feedback on the selections and provide alternative equipment options.

The project team spent most of 2023 troubleshooting software issues. This included multiple meetings with the software provided, and a complete system reset. Performing a factory reset

requires a manual rebuild and configuration of the files. Once the GC system was restored, blends of 5%, 10%, and 20% hydrogen in a balance of methane were evaluated.

Gravimetrically prepared blends of 0%, 5%, 10%, and 20% hydrogen in methane were then analyzed against each of the calibration blends to determine the instrument's precision, accuracy, and bias for each condition.

The evaluation of the data in early 2023 determined the instruments tracked well at the lower concentrations (5% LEL and 10% LEL) while showing a higher bias for all of the gas mixtures, including the 100% methane, at higher (20% LEL and 40% LEL) concentrations.

A draft final report is being prepared.

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Project No. 7.21.f

Establishing an Auditor Training Program for Differentiated 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.

Deliverables

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.

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.

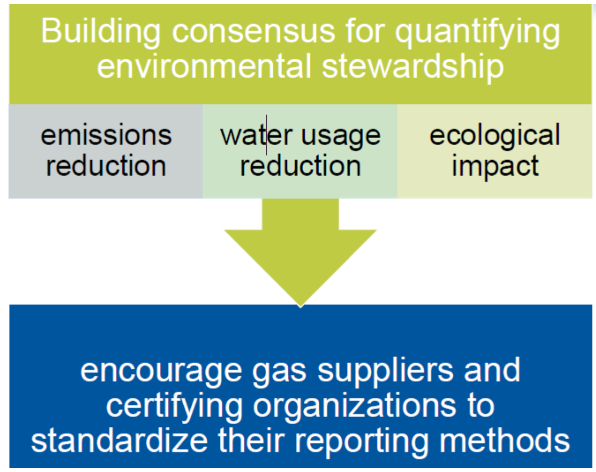
Third-party auditing is envisioned as an important element of certifying rubrics within different differentiated gas scenarios. When the differentiated gas initiative framework and protocols become available, end users and auditors will need training to ensure adoption of the new measurement-informed 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/Status

In Q2 of 2021, Veritas development began. A draft version of the protocols was developed and shared with participants in 2022 for input and feedback on the testing. In person meetings were also held in 2022.

The first version of the protocols was made publicly available in February 2023. After months of rigorous industry testing and comprehensive feedback, the updated Veritas Version 2 Protocols for site-level measurements were released in December 2023. The Veritas source-level measurement and reconciliation methodologies were made publicly available in February 2024. These protocols provide a more streamlined, refined, and standardized approach to accurately measure methane emissions. This, in turn, supports reduction efforts of global methane emissions.

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PSI Laser QGI Field Testing Phase 2

Researchers will evaluate advanced proto-types of the Remote Methane Leak Detector - Quantitative Gas Imager (RMLD-QGI) developed by Physical Sciences Inc. (PSI) which could significantly reduce the cost of Optical Gas Imaging for methane leak inspections.

Project Description

This project will evaluate advanced prototypes of the Remote Methane Leak Detector - Quantitative Gas Imager (RMLD-QGI) developed by Physical Sciences Inc. (PSI). Collaborating with Heath Consultants Inc. (Heath), GTI Energy (GTI), and OTD members, this project will support demonstration testing to evaluate performance of the advanced prototype QGI. Performance evaluation and feedback will be obtained though use of the QGI in real-world settings of distribution system leak surveys. The project's ultimate goal is to complete rigorous validation tests demonstrating that this technology: a) is convenient to use in real-world downstream municipal leak survey operations as well as upstream Leak Detection and Repair (LDAR); b) meets stated performance specifications; and c) can be used to both find and prioritize leak repair.

The first project Phase was completed and validated performance at the GTI laboratory (Figure 1). The QGI demonstrated its ability to survey, image and quantify natural gas leaks at meter sets. The technology was also demonstrated at compressor vents and underground leaks. The second project Phase proposed here will validate performance at real -world sites, improve the concept of operation for ground leaks, and obtain end-user feedback to further improve the technology.

In a parallel NIOSH (National Institute of Occupational Safety and Health) Phase 2 SBIR (Small Business Innovation Research) program effort, the overall system was miniaturized to a handheld unit with software and firmware optimized for stand-alone operation. The operating techniques and algorithms for deducing methane flux (i.e., emission rates), and emission sources were advanced and optimized using the controlled field test data.

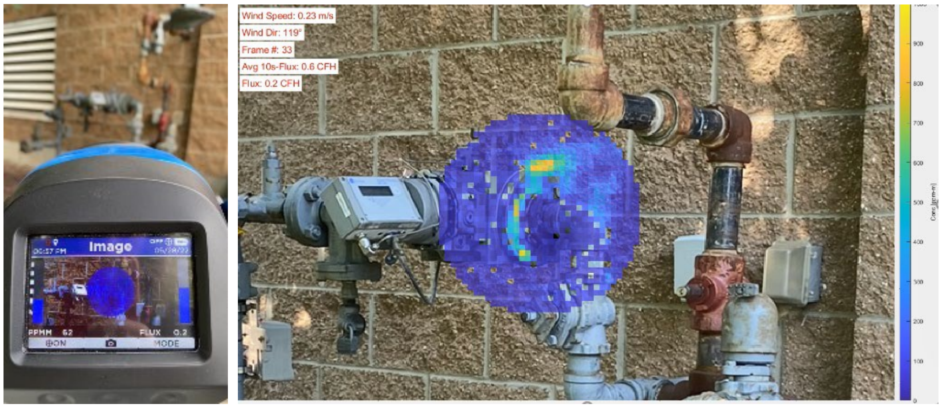
The QGI provides the user images of the background scene overlaid with two-dimensional spatio-temporal maps of path-integrated methane concentration versus position. It is capable of gathering these images from distances (50-100 feet) safely away from the source of the plume. Knowing the local air speed and direction, the tool estimates methane emission rates and path-integrated concentrations. For LDCs, the use case will be offering a relatively quick method to roughly estimate leak size to inform leak repair prioritization efforts.

Deliverables

Along with a final report, deliverables for this project include a final conference/webinar to review the results of this phase of the program and detail the next Phase for commercialization and implementation.

Benefits

A 2013 study prepared by the office of US Senator Edward Markey, summarizes the national impact of natural gas leakage. Most of the ~250 billion cubic feet of annual leakage volume originates at a relatively few large leak sites. Identifying and repairing those leaks is expected to mitigate approximately 90% of the loss, worth about $2B. 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. Quantitative Gas Imaging provides emission rate at each inspection site, enabling prioritizing the severity of the leak for



Snapshot of meter set showing a gas leak.

repair. This allows the operating companies to focus their repairs on larger leaks.

There is potential for QGI to reduce costs and training time due to its relative ease of operation.

Technical Concept & Approach

The primary tasks for this project include:

QGI Instrument Readiness

Prepare the advanced prototype(s) for field testing. Preparations will include system calibration, and bench testing. System calibration includes laser operating parameters setup, system parameters setup, optical alignments, and two-point measurement calibrations. Bench testing includes system noise characterization, user interface operational testing, and controlled release tests for verifying measurement performance and display of instrument features and functions.

Simulated Real-World Municipal Leak Testing

Develop test plans for conducting simulated real-world municipal leak surveys. Each end-user may have a unique test plan adapted to their locations and survey procedures. QGI performance will be documented. End-users will be trained in operating the QGI, and feedback will be collected to improve the QGI product.

The subtasks include:

- Define test plans that include test locations, duration of tests, and test dates.
- Devise a routine to train end-users in the operation of the QGI.
- Compose and implement an end-user questionnaire to collect feedback on the training, handling, operation, and reporting features of QGI.
- sequential field tests at 3 or more selected municipal survey areas or testing facilities meant to emulate real-world conditions.
- Analyze field test data and summarize the findings. Based on user feedback, include minor QGI modifications and updates between sequential tests.

GTI will conduct direct flux measurements of a subset of the leaks to compare with the QGI method.

Results/Status

Initial trials with the instrument at a test facility will begin in May 2024, followed by additional testing with a project sponsor in June 2024. Other sponsors have expressed interest in hosting field trials, and the planning is ongoing.

PSI is currently updating software and preparing the QGI instrument for field study. Additional calibration and preparation will be made as host sites and timelines are confirmed. This work will continue until field testing approaches.

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Project No. 7.21.j

Assessing Performance Impacts of Blended Hydrogen on Thread Sealants

Researchers will study the impacts of hydrogen blended natural gas on specific components in the distribution system, specifically thread sealants typically used on meter set assemblies (MSAs).

Project Description

The use of hydrogen and hydrogen-natural gas blends in traditional natural gas networks has increased in recent years. Operators are seeking to better understand and manage the risks associated, including the longer-term effects of hydrogen on transmission and delivery equipment. Hydrogen, in certain concentrations, may introduce embrittlement in metal or polyethylene materials. Understanding these risk areas is essential to establishing a safe hydrogen-blended system.

The goal of this project is to observe the impacts of hydrogen blended natural gas on specific components in the distribution system, specifically thread sealants typically used on meter set assemblies (MSAs).

Deliverables

The deliverable for this project will be a final report detailing observations and findings from the project.

Benefits

As the use of hydrogen blended natural gas increases it is important to understand and manage potential risks that may arise. This project will establish a baseline understanding of the effect hydrogen blended natural gas has on sealants within delivery infrastructure.

Technical Concept & Approach

The project team will work closely with to ensure the test rig being developed in OTD project 5.21.t "Effect of hydrogen blended natural gas on the performance of gas meters and diaphragm type service regulators" –will meet the requirements of this project. Testing will focus on thread sealants and the differences between different blends of hydrogen/natural gas and typical natural gas. Tests will be performed using a combination of gas and mixtures including no-blend natural gas and 20% hydrogen blend. The project team will analyze results and compare the impacts of blended and non-blended gases on samples. Fittings will be inspected for degradation due to hydrogen-blended natural gas.

Results/Status

Due to delays in the construction of the hydrogen rig that was planned to be used for this project, the team decided to use pre-blended gas cylinders instead of the gas from the OTD 5.21.t test flow loop. In 2023, a new test plan, sampling plan, bill of materials, test protocol, and job safety analysis were created. Testing is expected to begin in Q1 of 2024.

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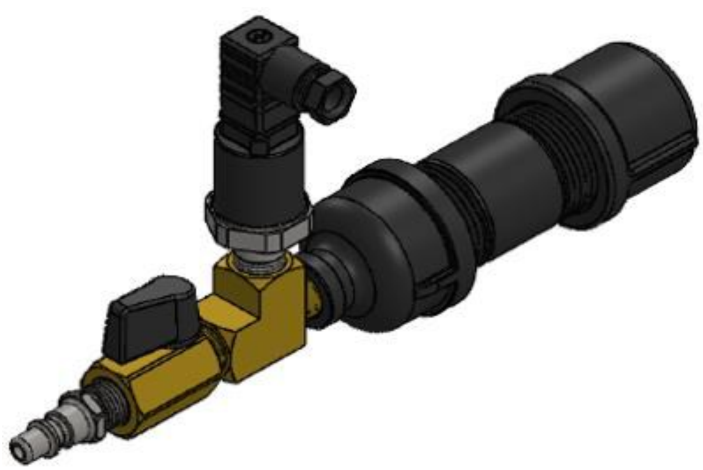


Pressure Transducer Subassembly attached to Black Steel 1 NPT Test Sample

Operations Technology Development

Evaluating the Potential of Algae Capture of CO_2

The goal of this project is to evaluate the potential of different carbon dioxide (CO_2) capturing methods for delivery of CO_2 to microalgae growth for production of RNG

Project Description

Development of innovative CO_2 capture technologies that can reduce the carbon footprint and convert to value-added products are of interest to multiple stakeholders. One of the emerging CO_2 capture technologies is algae -based CO_2 sequestration and conversion. GTI Energy and others have found value in bioenergy production coupled with carbon capture and storage as a method to create a negative emission power cycle and simultaneously produce renewable energy using microalgae. Recently, several companies have begun their investment in algae-based product commercialization activities.

In this project, the research team is experimentally evaluating the effectiveness and compatibility of several of these methods that have the ability to deliver CO_2 to microalgae culture and enhance RNG production. Different microalgae species will be evaluated for their growth and RNG production.

Deliverables

- Identification of CO_2 capturing methods that could deliver CO_2 to microalgae growth.
- Identification of microalgae species that could grow under varying solvent conditions and produce RNG/biofuels.
- Optimized methods for RNG and biofuel production using flue gas CO_2 capturing techniques.
- Final report on identification of methods for delivery of CO_2 from flue gas fire plants to microalgae farms for RNG production and greenhouse gas (GHG) emission reduction .

Benefits

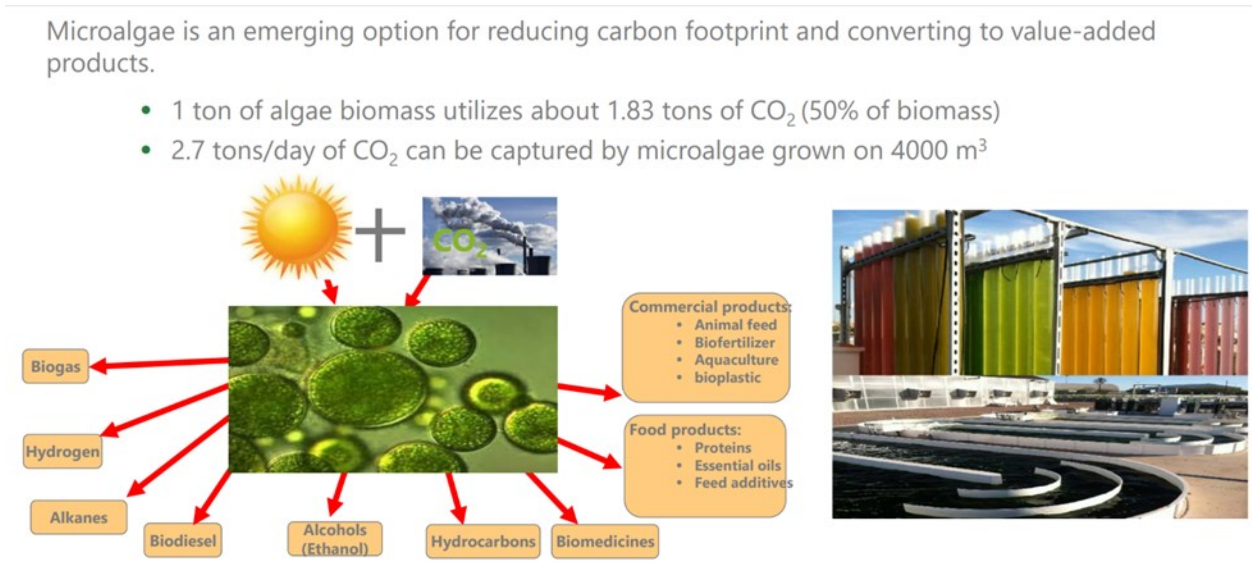
Technologies that contribute to GHG emission reduction are crucial for energy companies to decrease the carbon footprint. Microalgae technology creates a negative emission power cycle by capturing and storing CO_2 while simultaneously producing renewable energy. This will contribute to GHG emission reduction and produce value-added products such as renewable natural gas (RNG), biofuel, and other commodities used for various applications .

Technical Concept & Approach

Microalgae are known to produce biomethane. In addition, the biomass produced from algae can also be used as a feedstock to obtain value-added products including production of biofuels and revenue generating commercial and pharmaceutical products. The important attributes of algae are that it efficiently utilizes CO_2 as their carbon and energy source for growth, has higher photosynthetic efficiency, high CO_2 fixation capacities, easily optimized growth conditions, and has higher growth rate than conventional crop plants.

The key issues in algae-based technology are the means of capturing CO_2 at the source and transporting and delivering it to be used at an algae farm which is usually far from the emission source. In a prior phase sponsored by SMP, the project team identified several CO_2 capturing methods that are relevant to microalgae technologies. These include mineral carbonations, adsorption on carbonaceous materials, membrane capturing, aqueous ammonia, amine-based capture, microencapsulation, enzyme systems, and enzyme mimicry compounds.

The project will include laboratory experiments to monitor microalgae growth and RNG production using different CO_2 capturing methods. Commercially



available CO_2 capturing methods are being identified and evaluated for delivery of CO_2 to algae culture. Different microalgae species, such as halophilic (growth at high salinity), alkaliphilic (growth at high alkalinity) and thermophilic (growth at high temperature) algae species will be obtained from commercial sources and evaluated for their growth rate and RNG production.

High priority issues this project will help resolve include:

- Identifying capturing methods that could deliver CO_2 to microalgae farms to reduce GHG emissions (GHG emission reduction).
- Identifying microalgae species that could grow on the identified CO_2 capturing (Opportunity Identification).
- Optimizing condition for RNG and biofuel production (Method Optimization).
- Evaluating the RNG/biofuel production and biochar formation for use in nutrient capturing (Circular Economy).

Results

The project commenced with purchase of all algae and carbon capture reagents including a 15-position bioreactor that can run each position simultaneously with agitation and continuous measurement of methane and CO_2.

After formulation of the optimal media for the growth of the microalgae species, carbon capture experiments started in Q2 2023. Seven chemicals were identified that could capture and deliver CO_2 to the algae culture. The highest CO_2 capture was observed with compounds like ethylenediamine, monoethanolamine (MEA), dipropylamine, and polyethyleneimine.

Tests of algae growth using growth media amended with these carbon capturing compounds to determine if the compounds could deliver carbon dioxide to the microalgae continued throughout 2023. Several algae species were successful in the presence of ethylenediamine, monoethanolamine, dipropylamine, and diethanolamine. Polyethyleneimine did not yield any successful growth of algae species suggesting it may be toxic to the algae .

Status

The project team is finishing up the bioreactor experiments in anticipation of publishing the final report in Q2 2024..

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OTD Operations Technology Development

Food Waste Biogas Trace Constituents

Laboratory experiments with anaerobic digesters and food waste sources to gain knowledge of gas phase trace constituents that could occur in biogas.

Project Description

The greenhouse gas reductions of renewable natural gas (RNG) are essential for net-zero carbon goals of many utilities. As opportunities for these renewable projects arise, questions with regards to gas interchangeability and trace constituents will need to be addressed. This project seeks to answer these questions through experimentation with samples of common food wastes as feedstock for anaerobic digestion (AD), with analysis of the biogas produced for trace constituents of interest.

Deliverables

The deliverables of this project include data on the trace constituents and microbial community found from the anaerobic digestion of various food sources such as cereals, fruits, vegetables, meat, etc.

Benefits

The demand for renewable natural gas is growing across North America as evidenced by the continually increasing investments in RNG production by utilities. Acceptance of RNG is growing with the introduction of new RNG pipeline injection points or its use as transportation fuel. The value of renewable identification numbers and low carbon fuel standard credits drives much of this increase because anaerobic digestion is an effective diversion strategy that creates energy from sewage sludge, wastewater, animal manure, and landfills. However, broad utilization of food waste lags, due to challenges related to the cost of transportation, low adoption strategy by consumers, and unknowns related to the AD process.

The information gained from identifying trace constituents generated from specific food categories (cereals, fruits, vegetables, meat, etc.) would help in managing food waste streams and optimizing biogas to RNG production.

Technical Concept & Approach

This project is characterizing biogas produced from bench scale anaerobic digesters where the feedstock is food waste to understand what trace constituents may derive from specific food waste items.

AD experiments are being carried out in serum bottles and bioreactors in GTI Energy's Environmental and Microbiology lab. Food waste from different sources is sorted from non-food materials and processed as unique feedstocks for the digester experiments. The processed food waste is

Components of BPC Gas Endeavor installed in GTI Energy's bioreactor room.

added into serum bottles anaerobically and monitored for biogas production. Samples are withdrawn periodically from the bottles to determine the microbial community and chemical composition of the liquid and gas produced. Analyses focus on identifying trace constituents in the gaseous phase such as volatile metals (arsenic and others), volatile organics, and terpenes.

A complex mix of food wastes will be used as a substrate for the first anaerobic digestion experiment. The substrate will be combined with the inoculum grown during the instrument commissioning experiment along and compared to inocula from other sources. The inocula capable of producing the most methane using only food waste will be selected for the "single source" anaerobic digestion experiments.

Results/Status

The project was kicked off in 2022, with input from sponsors on what specific food sources would be of interest for testing. This list included common food waste items that could contain substances of concern, such as terpenes found in citrus that could interfere with odorants.

Specialized equipment to facilitate the analysis of biogas samples was selected and procured. In 2023, The BPC Gas Endeavor instrument (Figure 1) was received and installed in GTI Energy's bioreactor room where the biogas produced in the experiments is isolated from the primary office and lab space. Since the instrument is capable of being controlled and monitored remotely, the bioreactor room was wired to accommodate internet connectivity. The project team worked with BPC train on instrument operation and confirm functionality.

In Q4 2023 the lab started collecting the specific food wastes identified for this project. These wastes will be combined to serve as a complex substrate for the first anaerobic digestion experiment.

A complex mix of food wastes will be used as a substrate for the first anaerobic digestion experiment. The substrate will be combined with the inoculum grown during the instrument commissioning experiment along and compared to inocula from other sources. The inocula capable of producing the most methane using only food waste will be selected for the "single source" anaerobic digestion experiments.

The project is ongoing and is anticipated to be completed in 2024.

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Review of Emissions Quantification for Distribution Systems

This project's focus is to develop a report with a list of methods and technologies used by local distribution companies quantifying how they reduce methane emissions.

Project Description

Recently, methane emissions detection, methane emission quantification, and ways to reduce those emissions have received attention through new corporate initiatives, changes to the US Environmental Protection Agency's (EPA) Greenhouse Gas Inventory (GHGI), and the passing of the Protecting Our Infrastructure of Pipelines and Enhancing Safety (PIPES) Act of 2020. Utilities are working to enhance how they identify, report, and work to reduce both fugitive and operational methane emissions.

The scope of the project has three main areas: identifying methane emission sources in distribution, understanding emission quantification methods (measurement and calculation), and highlighting opportunities for emissions abatement.

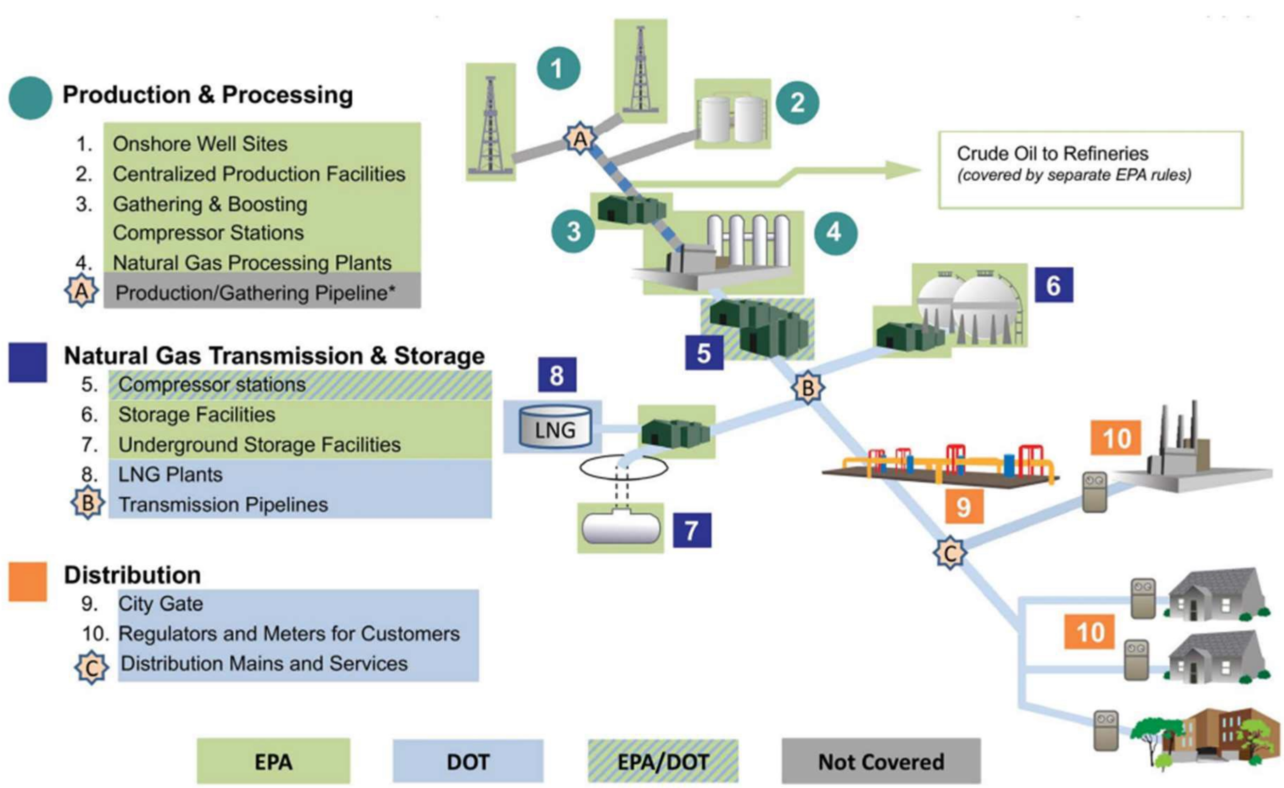
Deliverables

A final report which summarizes the finding of the information gathered.

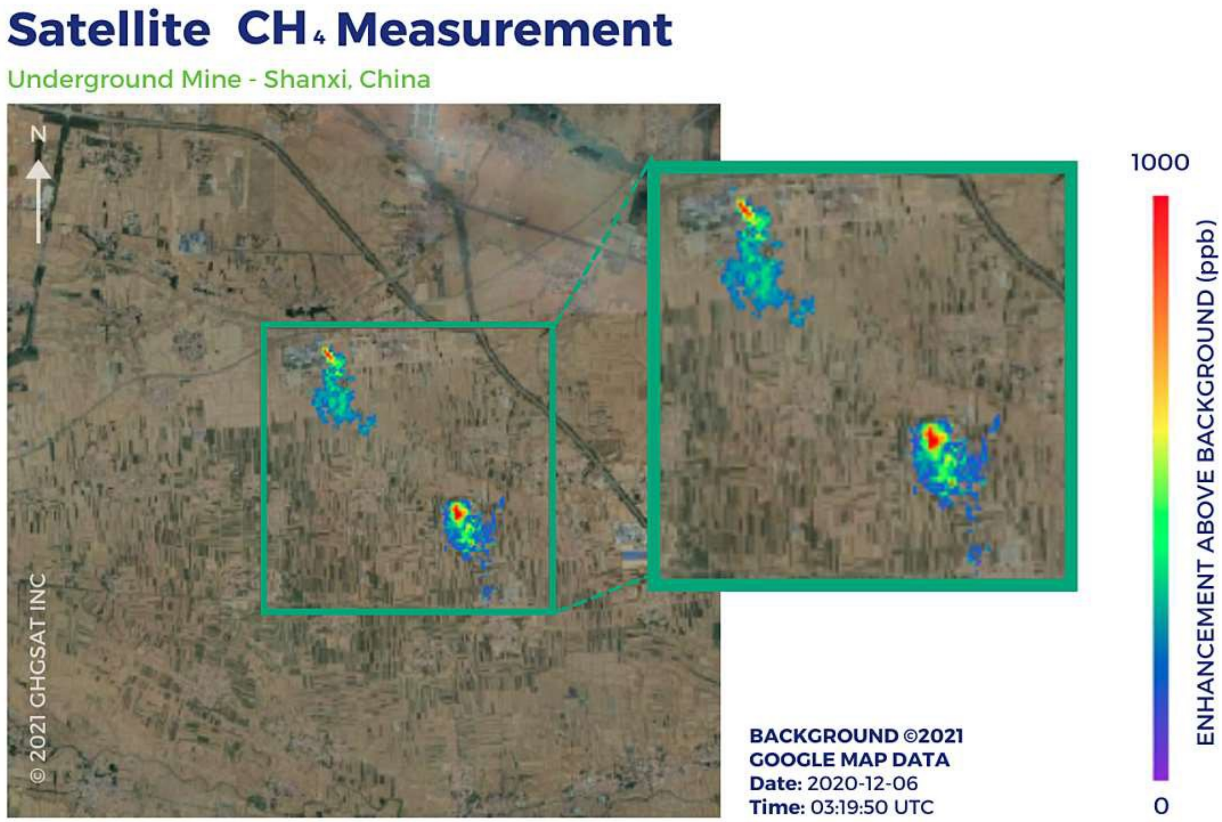
Benefits

The report generated from this project provided detail about the potential sources of methane that operators can reduce in the system, potential solutions (existing and emerging) for reducing those emissions, ways those emissions are calculated, and accepted methodologies for quantification.

Crude oil and natural gas industry: Where EPA and DOT methane emissions rulemakings would apply



Adapted from American Gas Association and EPA Natural Gas STAR Program
**PHMSA regulates some gathering pipelines*



Technical Concept & Approach

The landscape of methane emissions measurement, detection, quantification, abatement, and regulations is large and rapidly evolving. The main purpose of the project/white paper was to bring these topics together into a single succinct reference document. The summary presented in this white paper represents a snapshot in time amid rapid change. This paper is meant to provide foundational knowledge that can be updated as new technologies/techniques for measurement and abatement are brought to market and new regulations are introduced. It is intended to provide operators, managers, and technology manufacturers with an overview of methane emissions reductions strategies.

Results/Status

The final report was issued in March 2023 focusing on the four areas described above, followed by a webinar in April 2023 to review report findings and gather sponsor feedback. The report summarizes the current state of understanding and reducing methane emissions. The report is divided into four sections:

- Methane emissions inventories and calculations
- Current landscape of existing and emerging technologies and methodologies
- Methane emissions abatement
- Regulations

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Carbon Monoxide Sensor Interference from Hydrogen

As hydrogen (H_2) is integrated into fuel gas for distribution, concerns arise about potential interference with carbon monoxide (CO) sensors found in residential and personal detectors. Through a series of laboratory tests, this project evaluates the rate of false positives on carbon monoxide (CO) sensors in the presence of hydrogen (H_2) at various concentration levels.

Project Description

In addition to the use of odorants to alert the public of a gas leak, Fuel Gas Detectors (FGD), also known as Residential Methane Detectors (RMD), and Personal Gas Monitors (PGM) improve safety by acting as an early warning system for unreported or undetected gas leaks. The impact of hydrogen blends on the performance of FGDs and PGMs is unknown, as they are not designed to function in presence of hydrogen. Recent OTD projects "*7.20.m Impact on RMD Performance from Hydrogen Blended into Natural Gas*" and "*7.20.h PGMs – Performance, Interferences, and Hydrogen Impact*" showed that the presence of hydrogen had an impact on the CO sensor found in multi-gas detectors and monitors. False CO alarms went off when detectors were exposed to hydrogen blended with methane and no carbon monoxide present.

Nine different models of FGDs and PGMs from seven brands were used in this study. The FGD brands were Kidde and Universal. The PGM brands were Blackline, Honeywell, MSA, RKI, and Sensit. The focus for this project is only the CO sensor in each unit.

Deliverables

A final report will be drafted which summarizes the data on the responsiveness of nine selected residential fuel gas detectors and PGMs after exposure to different mixtures of air blended with hydrogen.

Benefits

This work will advance understanding about the behavior of CO sensor alarms with hydrogen blends, for utilities and first responders. CO is an odorless, colorless gas that is produced from the combustion of fuel. Because of the dangers of CO in sufficiently high concentrations, detectors or alarms are required by code or statute in 47 out of 50 states in the US, and 6 out of 13 Canadian provinces. PGMs are commonly used by gas industry personnel to provide a warning of increased methane levels. PGM devices are often coupled with hydrogen sulfide, CO, and oxygen sensors in a single wearable unit. With expanded hydrogen blending on the horizon the impact on sensors used in these safety devices must be evaluated. Avoidance of false alarms is a critical need.

Technical Concept & Approach

This project evaluated performance of a selected group of residential fuel gas detectors and PGMs for false positive CO responses in the presence of hydrogen at chosen levels. Data recorded was a determination of pass or fail dependent on if the CO sensor in each device made an audible alarm. The nominal hydrogen concentrations were tested in this project are 25, 50, 125, 250, 500, 750, 1000, 1250, and 1500 ppmv.

Figure 1: Alternate testing chamber

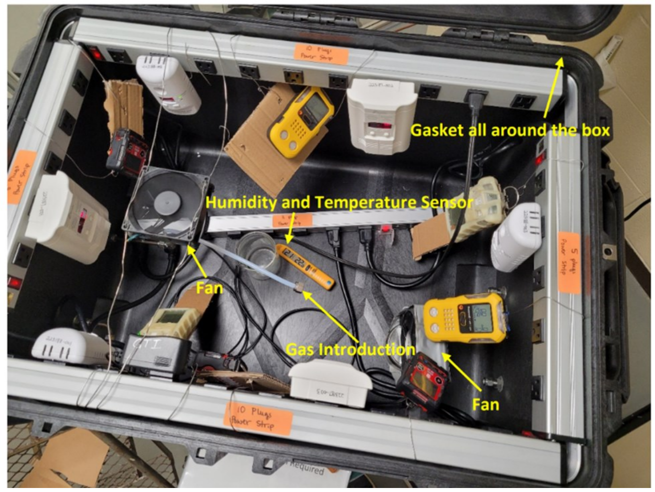

Figure 2: Testing setup in Black Box

Results

The final report was issued in March 2023. This study showed the units with poorest performance responded at the lowest hydrogen concentration (25ppmv). Only three did not respond at 125 ppmv, two of which had H2 compensated sensor. At 500 ppmv, all of the detectors except for the one with H2 compensated sensor responded to hydrogen. Some units were not tested at the higher concentrations of hydrogen because they did not pass at the lower hydrogen concentrations. Rankings of the units tested can be found in the final report. Ongoing tests in another OTD project, 7.21.d “Accuracy of H2 Analyzers and Survey Instruments”, will show if other combustible gas detectors used for leak surveys will experience the same type of hydrogen interferences .

Status

The Final Report was completed in February 2023.

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Veritas Methane Emissions Measurement and Verification Initiative

Veritas, a GTI Energy Methane Measurement and Verification Initiative, is a standardized, science -based, technology neutral, measurement-informed approach to calculating and reporting methane emissions.

Project Description

Natural gas operators are working to reduce releases across their system to meet climate and environmental goals. Accurate measurement is the first step towards demonstrating credible reductions of methane emissions. Veritas is designed for this explicit purpose. Veritas provides different protocols for each segment of the natural gas industry to measure methane emissions in a consistent, credible, and comparable way.

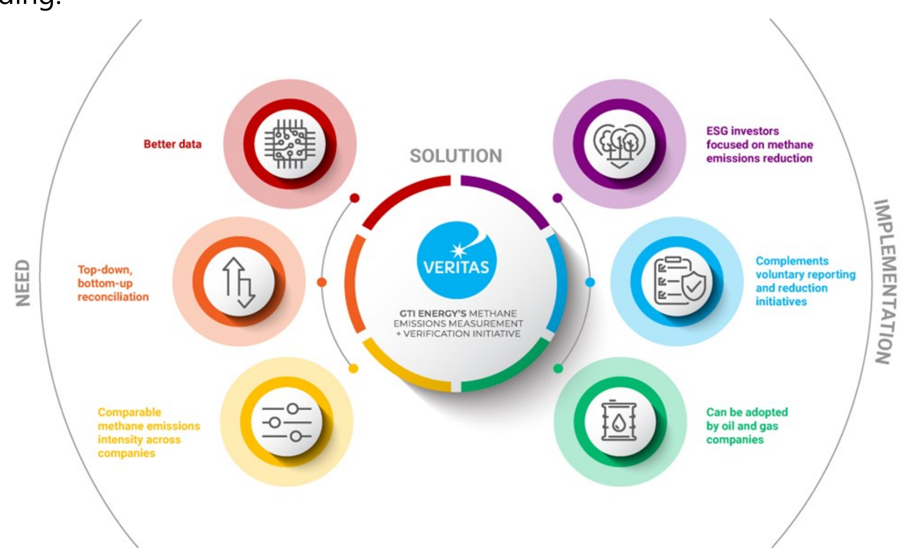
Deliverables

- Issued white paper in Q1 2023 around Year 1 demonstration project learnings
- Published documents addressing uncertainty in emissions measurement and quantification and data collection.
- Implement communications strategy to facilitate stakeholder awareness and understanding.

Benefits

Widespread adoption of the Veritas protocols will result in consistent, trustworthy data that will allow investors and other stakeholders to rely on a fundamental methane emissions key performance indicator that will be used by industry. By establishing a standardized methane measurement methodology, companies, investors, and policymakers will have an accurate inventory of methane emissions that can be compared across supply chains for collaborative reductions.

The Veritas protocols are the building blocks to provide global confidence in the climate credentials of natural gas. The protocols provide companies with guidance on how to measure their methane emissions and reconcile current emission factors with actual measurements. This will allow companies to reduce their methane emissions, participate in certification schemes, and meet import or procurement requirements that are tied to methane intensity more effectively.



Veritas is the solution between the need for better data, top-down and bottom-up reconciliation, comparable MII across companies and implementation with ESG investors, voluntary reporting and reduction initiatives with adoption by oil and gas companies.

Veritas 2024 Goals

- **Implementation Assistance**
  - Support companies utilizing Veritas from sample planning to report writing.
  - Continued support documentation to be provided around sample planning, data collection, and measurement uncertainty.
- **Continuous improvement and educational outreach of Veritas protocols**
  - Adapt protocols, as needed, to be in alignment with state, federal, and international regulations.
  - Support testing of source-based methane emission measurement campaigns for companies looking to develop Level 4 OGMP 2.0 reports.
- **Government partnership**
  - Participation of GTI Energy and Veritas in stakeholder group for international MMRV run by U.S DOE.
  - Feedback from the scale-up of Veritas to basin-wide scale through DOE iM4 and LNG value chain.
- **Veritas Role in Carbon Accounting**
  - Utilize Veritas reports to support supply chain emission estimates for the natural gas industry.
- **Audit and Assurance**
  - Work with auditing companies on Veritas assurance and training on Veritas Protocols.

Technical Concept & Approach

Veritas is an ongoing initiative, and OTD funders participate in several ongoing efforts, such as those outlined below:

Scaling Veritas and Continuous Improvement

- Testing protocols across more companies.
- Gathering feedback through regular Technical Project Committee meetings and workshops

Educational Outreach & Shared Learnings

- Providing outreach to financial community and regulators to inform them about Veritas
- Issuing white papers periodically to demonstrate project learnings

Ensuring Veritas is widely accepted and adopted

- Publishing documents addressing uncertainty in emissions measurement and quantification and data collection.
- Aligning Veritas with other initiatives
- Implementing communications strategy to facilitate stakeholder awareness and understanding.

Results

Published in February 2023, the Veritas Version 1 technical protocols (https://veritas.gti.energy) cover six segments of the natural gas supply chain, ranging from upstream to downstream (production, gathering and boosting, processing, transmission and storage, distribution, and LNG). These technology neutral protocols are designed to allow for a comprehensive toolbox of technologies to be used in the service of accelerating methane emissions reductions. GTI Energy has solicited input from a diverse group of stakeholders to ensure the methodology is widely accepted and adopted. Stakeholders include academics, environmental NGOs, companies, investors, policymakers, and vendors.

GTI Energy will publish and maintain these protocols as open-source, technical tools that many different stakeholders around the world can utilize and operationalize.

Status

Veritas Version 2 of the protocols was published in December 2023 .

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Evaluation of Current Advanced Mobile Leak Detection Systems

The primary objective of this project is to evaluate the leak detection performance of advanced mobile leak detection systems. The work will be focused on conducting a single/double blind study of current commercially available systems.

Project Description

Several commercially available Advanced Mobile Leak Detection (AMLD) systems exist. The variety of these systems, along with the emphasis placed on advanced leak detection technologies in the Protecting Our Infrastructure of Pipelines and Enhancing Safety (PIPES) Act of 2020, has created the need for an evaluation of these systems. The goal of the project is to develop a framework for evaluation of different technologies, including statistical analysis methodologies.

Deliverables

- Single-blind controlled field test
- Quarterly reports
- Final confidential and public report

Benefits

Leak detection equipment and methodologies have been developing rapidly for more than a decade. There is a need for operators across all natural gas segments to understand the performance and limitations of these new technologies.

One type of leak detection platform, the Advanced Mobile Leak Detection system (AMLD), has grown from a single offering from a manufacturer to include commercial products from several companies. Due to regulators pushing toward more advanced leak detection systems in general, it has become crucial to evaluate them to understand performance and to also determine the appropriate use cases for these systems. For instance, which systems can be used to count towards regulatory leak survey, which are better used as supplemental leak identification systems, and where these tools are used to quickly find leaks in parts of the system that are not being surveyed that year.

The PIPES Act requires all pipeline operators, including those in transmission and distribution, to adopt advanced leak detection technologies and practices to detect pipeline leaks.

Technical Concept & Approach

The scope of this project will be focused in three key areas:

1. Field deployment planning
2. Field deployment
3. Data/Statistical analysis.

Figure 1: Instrument installation on vehicle

The research team will structure the project with the following tasks:

Evaluation of as many AMLD technologies as possible. The efforts will focus on coordination with vendors for participation in the field study.

A test matrix will be based on the single-blind study method to evaluate AMLD system performance.

- The team will conduct a single blind field study in collaboration with one sponsor utility. The leaks and locations will be hidden from the advanced mobile leak detection systems and will be marked via GPS/GNSS device prior to the start of sampling each day.
- The vendors will be asked to survey a defined area each day that will include existing, graded, non-hazardous leaks. To neutralize differences in leak plume characteristics the technologies will be deployed to the same areas and leaks on each day of testing.
- Six leak sizes or bins will be used to establish probability of detection statistics.
- A statistical analysis and final report will be written based on the data collected in the field deployment.

High flow sampler connected to tarp enclosure over a simulated leak

Results/Status

In Q4 2022 and Q1 2023, multiple vendors were contacted about their potential involvement and multiple expressed interest and joined project.

The project team has developed the field-testing objectives and testing framework. The planned field testing incorporates 2 phases:

Controlled open field testing to establish and evaluate sensor performance as a function of multiple variables, e.g., speed, wind, distance, leak rate.

Gas Town testing using established leaks at an OTD member training facility. This phase will establish and expand upon the statistical sample size to produce the detection performance curves.

Field testing was completed in October 2023. Four mobile leak detection devices were installed onto one vehicle. Testing was conducted at a sponsor training facility where leak locations, flow rate, distance from the leak, and vehicle speed were varied in an open field.

Open field, controlled testing resulted in 65 individual tests being conducted, with each test repeated five times. The leak rate was precisely controlled using a mass flow controller.

Gas Town testing resulted in 22 individual tests being completed, with each test repeated 5 times. The flow rates of the tests were measured using a high flow sampler device to monitor leak rate throughout the test using a tarp enclosure for underground leaks. Leaks were simulated with various weather conditions such as wind speed, rain, and location of the leak.

There were many complexities in the organization and evaluation of four vendors that ultimately participated in this effort. However, the engagement with vendors and execution of the field program was successful. Large volumes of data were collected for processing. Data analysis is currently ongoing.

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Predictive Corrosion-Rate Risk Model from Soil and Environmental Conditions

The primary objective of this project is to evaluate the potential use case for Optical Gas Imaging (OGI) cameras and handheld laser methane detectors to expedite identification of statistically large leaks in the distribution system.

Project Description

Relatively large emission sources (termed "super emitters") drive nearly all actual methane emissions from local distribution systems. Super emitters are often described as a relatively small number of leaks contributing a disproportionately large volume of gas emissions.

For instance, GTI Energy found in a recent U.S. Department of Energy (DOE) and OTD co-funded industrial/commercial meters study (Distribution System Characterization) that 10% of the leaks generated 72.5% of the total emissions from measured meters. Quickly identifying these larger emission sources, and prioritizing these leaks for repair, can help reduce the impact to the environment.

To conduct the testing required in this project, the project team will continue to build on the leak detection evaluation framework developed in the Pipeline Hazardous Materials and Safety Administration (PHMSA) and OTD project 7.20.b, "Validation of Remote Sensing and Leak Detection Technologies under Realistic and Differing Conditions."

The framework developed involves techniques that focus on balancing the tradeoffs between true positive (correct detections), false positives (detecting leaks when no leak is present), true negatives (detecting no leak when no leak is present), and false negatives (missing leaks). The techniques require examining probability of detection statistics and coupling that with receiver operating characteristic (ROC) curves and area under the curve (AUC) statistics.

GTI Energy also established a working relationship with the Methane Emissions Technology Evaluation Center (METEC) at Colorado State University during the PHMSA/OTD Project. METEC is a large-scale field laboratory developed under the ARPA-E MONITOR Program. METEC has over 200 aboveground, controlled leak release points on decommissioned oil and gas equipment. Making it the ideal location for testing the ability of the OGI cameras and handheld laser methane detectors to identify and locate leaks. The project team will conduct testing for this project at the METEC facility.

Deliverables

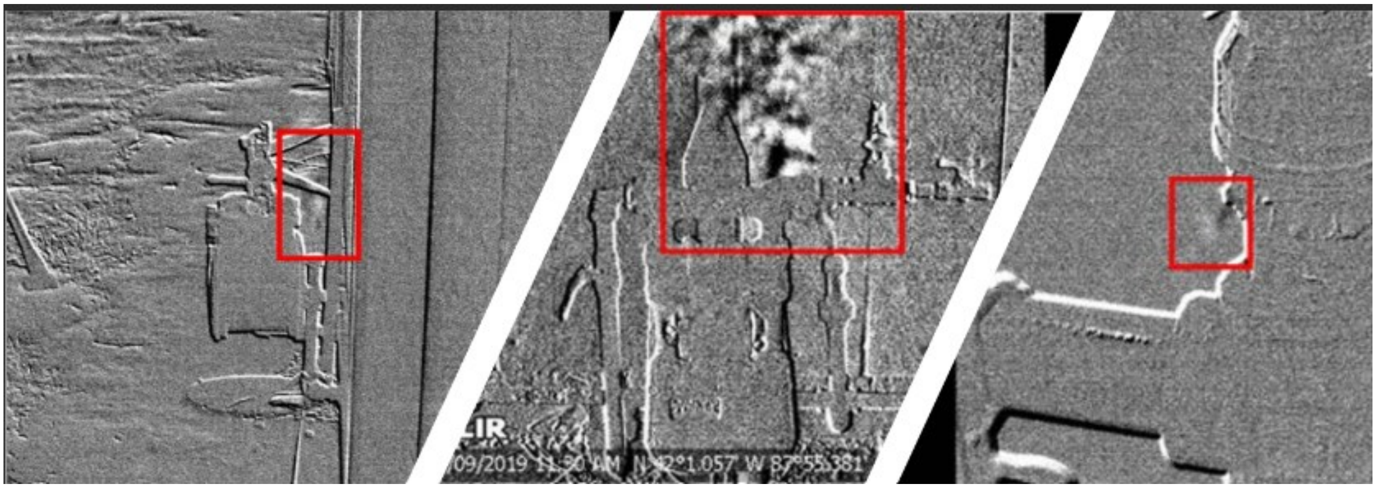
The following are deliverables for the project:

- Detailed test plan/matrix for testing at METEC
- Organized database of information collected
- Prepare a final report.

Benefits

Across all segments of the natural gas industry, there is an increased need to explore all options of reducing methane emissions from assets. Identifying methods that offer quick scanning and potential indications of the largest leaks on assets is helpful for operators to prioritize repairs and reduce their actual methane emissions with minimal impact to operations.

Several tools have been recently developed to expedite scanning of assets to identify leaks including handheld laser methane detectors, while other tools such as optical gas imaging (OGI) have been around for decades.



Captured gas leaks

Technical Concept & Approach

The project will be focused on evaluating the ability of OGI cameras and handheld laser methane detectors to identify leaks on higher pressure assets. To accomplish that the project will focus on planning and execution of a detailed field laboratory campaign followed by detailed data analysis.

The tools have a wide range of costs and capabilities, and as such, both tools offer strengths and weaknesses for identification and localization of leaks.

Results/Status

IN 2023, a field-testing plan was developed to simulate city gates, high pressure mains, industrial meters, or other higher-pressure assets. Contracting was put in place with METEC to host the field tests. Several vendors were identified to participate.

Due to scheduling issues work has been paused until the 2nd quarter 2024. This effort will require sole use of the METEC facility during the testing period. As such, adequate scheduling in 2023 was difficult due to previously planned testing campaigns at the facility as well as time conflicts with technology vendors. METEC testing was rescheduled to May 2024 and is on schedule.

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Open Hydrogen Initiative

The Open Hydrogen Initiative (OHI) is an international consortium of industry stakeholders led by GTI Energy and S&P Global Commodity Insights, with technical contributions from the National Energy Technology Laboratory (NETL). The mission of OHI is to establish the groundwork for a clean hydrogen market through the development of a globally harmonized life cycle analysis (LCA) toolkit.

Project Description

As global organizations accelerate their decarbonization strategies, hydrogen has emerged as a promising solution to decarbonize hard-to-abate sectors. However, energy markets lack a consistent and universally accepted methodology to assess the environmental credentials of a given unit of hydrogen. This information gap potentially jeopardizes the ability of decision-makers to make informed choices in policy, procurement, and investment. The success of low-carbon hydrogen necessitates a globally harmonized methodology to assess the carbon intensity of hydrogen production at the facility level, enabling transparent communication of crucial information to consumers, lawmakers, and producers. Currently, transparent, and credible asset-level measurement protocols and related tools have yet to be developed, creating a gap that hinders the commoditization of this essential energy vector.

OHI has convened a diverse range of stakeholders involved in the hydrogen marketplace, including experts from integrated majors, gas and power utilities, environmental non-governmental organizations (eNGOs), government agencies, academia, hydrogen production companies, coalition groups, and more. OHI stakeholders actively contribute to the development and execution of initiative goals. Since its public launch in February 2022, OHI has attracted over 40 members from various organizations.

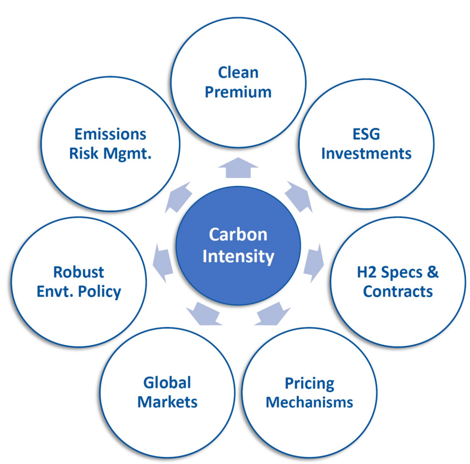
Deliverables

The OHI project will produce a briefing and memos, including reviews of hydrogen production data, material, and energy life cycle data to support hydrogen production, carbon management and co-product management practices.

In addition, there will be a summary of existing measurement protocols for reporting environmental data, an open-source tool: Global Hydrogen Life Cycle Analysis Tool/Toolkit, a public report: Hydrogen Life Cycle Modeling Protocol for Supplier Asset Level Measurement and Reporting, and four case study examples of tool and product applications.

Benefits

Hydrogen offers a promising pathway for gas-sector decarbonization, supporting the continued utility of pipelines, gas storage infrastructure, as well as CO_2 transportation and storage—strategic opportunities for the gas sector. However, the low-carbon hydrogen industry requires relevant information on the life cycle carbon intensity of hydrogen production to scale rapidly. OHI, by developing a



OHI Leadership

Foundational Sponsors

Technical Sponsors

NGOs, Academic Partners, and Observers

universal methodology, fills this information gap, ensuring the prevalence of low-carbon gas solutions through midcentury and beyond.

The methodology created by OHI facilitates industry growth by supporting hydrogen markets, technology-agnostic policies, clan hydrogen investment strategies, and standards for certified low carbon hydrogen. Additionally, it reduces the compliance burden through a single, transparent, practical, and clear assessment methodology, enabling the scaling of hydrogen markets and increasing demand for the energy used in production and the associated infrastructure.

Technical Concept & Approach

The technical development of the Open Hydrogen Initiative is broken down into seven primary tasks:

1. Review and assess the current state of the science of Life Cycle Assessment (LCA) modeling for hydrogen production and primary energy supply.
2. Review the current state of the science for carbon management and co-product management.
3. Develop a framework for assessing and quantifying the representativeness and reliability of measured data in alignment with industry techniques.
4. Develop a life cycle analysis framework and data management strategy to convey the representativeness and reliability of the underlying measured data.
5. Develop the LCA tool and associated protocols – Global Hydrogen Life Cycle Greenhouse Gas Emissions Tool and Guidance Documents.
6. Conduct demonstration projects and validation of the LCA toolkit and associated protocols.
7. Communicate project results on key milestones to industry participants, lawmakers, and other energy industry influencers.

Results and Status

Technical work commenced in September 2022, with stakeholders providing input and feedback through monthly sessions. During this period, the OHI team gathered technology-specific data and built a unique toolkit. With support from the OHI technical team and stakeholders, a beta version of the toolkit was completed, accompanied by a state-of-the-art Unit Process Library.

Four case studies were tested in the UK, Australia, Argentina, and the US. Webinar presentations covered topics such as LCA model comparison, insights on 45V GREET, and the data quality index. Memos were also compiled on technology literature reviews, data quality, and LCA tools.

The demonstration phase, featuring over 10 real -world hydrogen projects across three continents, began in December 2023. In March 2024, OHI was publicly released on a global stage at the annual CERAWeek conference.

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Voluntary Emissions Reduction Initiatives for Responsibly Sourced Oil and Gas

In 2021, Highwood Emissions Management published a novel report, "An Overview of Voluntary Emissions Reduction Initiatives for Responsibly Sourced Oil and Gas". The free public report helped industry make sense of opportunities to take credit for voluntary emissions reduction efforts (e.g. differentiated gas).

Project Description

The market for responsible gas is evolving and growing rapidly, and many companies and organizations across the value chain are seeking to understand the diverse voluntary emissions initiatives available.

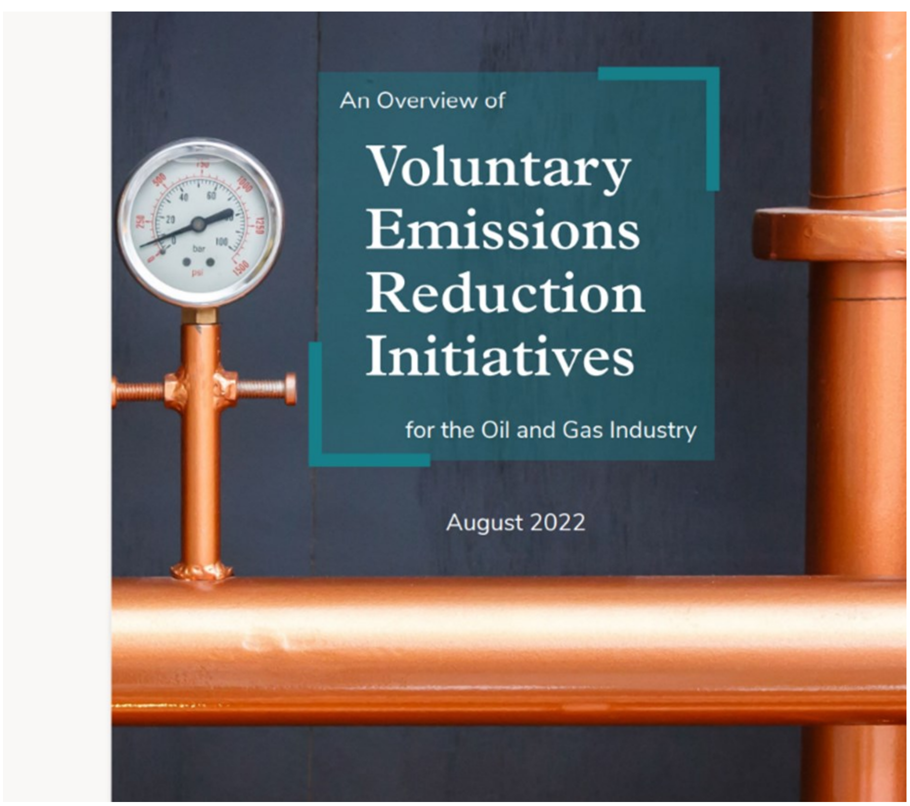
Highwood Emissions Management works with industry, government, and innovators around the world to collaborate, innovate, and educate for effective and affordable emissions management solutions. In May 2021, as part of its education mandate, Highwood published the first edition of *Voluntary Emissions Reduction Initiatives for Responsibly Sourced Gas* (RSG).

This project will expand and update the 2021 report to include how voluntary initiatives apply to natural gas delivery companies and exploring how the entire natural gas value chain can participate in RSG.

The 2022 edition has expanded and updated content on many of the world's leading RSG initiatives, as well as content targeted to key elements for stakeholders across the natural gas value chain.

Deliverables

This project will update and publish a new version of the 2021 report "An Overview of Voluntary Emissions Reduction Initiatives for Responsibly Sourced Oil and Gas".



Benefits

There are increasing numbers of commitments from energy companies across the entire supply chain to meet net-zero commitments. Differentiated products such as RSG and other voluntary initiatives provide an opportunity for companies to demonstrate progress towards these commitments.

To ensure the transport and delivery of RSG, the entire value chain must participate collaboratively through voluntary initiatives, however there are an increasing number of these initiatives and not all are applicable to every segment or region. Identifying which initiatives are most relevant to transmission and distribution companies will aid in deciding which practices are best for utilities, and how utilities can best take credit for participation in emissions reduction efforts.

Technical Concept & Approach

The following tasks were completed as part of the project.

- Identifying new and updated RSG initiatives, soliciting feedback on enhancements to report, setting deliverables, securing funding, and creating a questionnaire to send to RSG organizations.
- Processing information received from the questionnaires, additional research, and meetings with RSG organizations, and compiling and interpreting data.
- Compiling a report, peer, and sponsor reviews, editing, report design, and formatting.
- Public releasing the report, including marketing and awareness campaigns –including press releases, LinkedIn, webinars, podcasts, and courses.

Results

The project team worked with Highwood Emissions to produce the report in Q3 and the team presented the report to sponsors.

Status

The final report was publicly released in October 2022.

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Predictive Corrosion-Rate Risk Model from Soil and Environmental Conditions

Researchers will develop a quantitative risk assessment model to identify high corrosion potential in order to better understand the state of existing pipelines and more efficiently conduct maintenance.

Project Description

Environmental conditions, age of the infrastructure, and soil conditions are significant parameters which affect measuring, predicting, and mitigating corrosion. Other OTD and GTI Energy projects for PHMSA on the evaluation of external corrosion-rates have provided estimates of corrosion rates from soil properties and field data.

The team will use this knowledge to develop a quantitative risk assessment model to identify high corrosion potential. The tool will be a web-based program using parameters based on their effect on corrosion potential and quantifying corrosion growth-rate estimates in a Bayesian model for a risk assessment of the pipe segment.

Deliverables

The main deliverable, along with the final report, is a risk assessment program for estimating corrosion potential based on corrosion rates. The assessment will assist in the decision making of mitigating the threat though monitoring, repair, or replacement of the affected segment. The tool will be provided in a web-based program.

Benefits

The project presents an integrated approach for the evaluation, prediction, and mitigation of external corrosion risk. For belowground pipes, work investigates the effect of electro-chemical properties of the surrounding environment, including electrical resistivity, alternating current, moisture content, and soil properties.

The outcome of the project incorporates corrosion inspection data and develops a corrosion growth-rate prediction model in a web-based software for risk assessment. Results from field data will be used to validate the corrosion potential of selected sites. This approach will help in identifying high-risk locations, monitoring procedures, and inspection intervals. The output would also help in recommending modifications to the leak/corrosion monitoring procedures. This approach mainly addresses corrosion in belowground lines. Atmospheric corrosion threat to aboveground facilities is affected by a different corrosion mechanism but may be added in follow on efforts.

Using this model, operators will have more insight into the state of their pipelines and will be able to more efficiently direct their resources when conducting maintenance. In addition, the Gas Distribution Integrity Management Program (DIMP) requires evaluating and ranking this risk to the pipeline system. CFR Part 192- Subpart O for pipeline integrity management also requires establishing a reliable estimation of corrosion growth-rate.

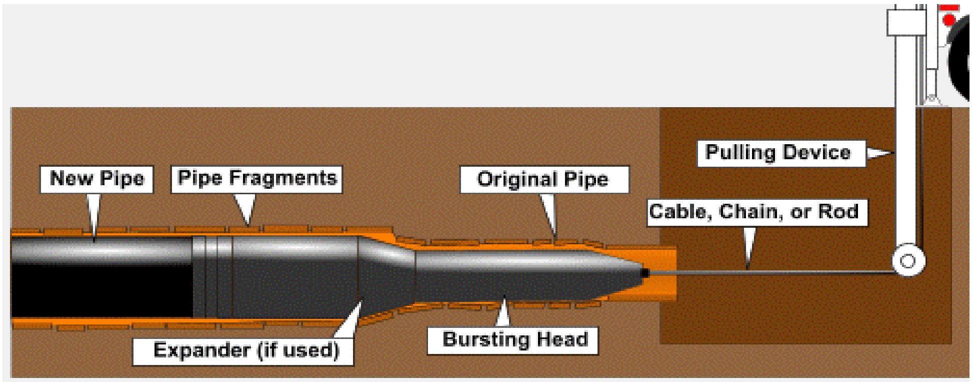
Technical Concept & Approach

Establish A Data Form for Corrosion Monitoring Procedures

Review corrosion and leak-related data from previously recorded inspections. Categorize corrosion inspection (such as light, moderate, and severs corrosion), based on metal loss values when available. Estimate related soil conditions from soil survey records and utility records when available.

Correlate the Data System

Incorporate the data into a web-based program linking historical data and field inspection sites with



Pipe bursting repair

other soil and environmental conditions. Develop a user interface for data entry and search.

Evaluate Soil and Environmental Parameters

Correlate electrochemical measurements of corrosion potential to soil conditions to predict a growth-rate from measurements and historical data, including soil properties, pipe history, and field conditions into the correlation. Examples of anticipated field data include soil moisture content, pH, resistivity, permeability and drainage characteristics, chloride and sulfite levels, and soil Redox potential. Many of these parameters can be obtained from existing soil survey data.

Incorporate Data in a Web-Based Risk Management Program

Develop a risk model to combine soil parameters and historical data with existing correlations in the literature between soil properties and corrosion potential. Develop a computer program to present the results of the analysis in a simplified format that provides estimated corrosion-rate and quantifiable risk assessment using a Bayesian Networking approach, including a user interface which allows the user to enter relevant site data to improve the reliability of risk ranking determination of the pipe segment.

Results/Status

The team first conducted analysis to determine that natural and outside forces are a larger threat to older cast iron pipes compared to gas distribution pipes more generally. External repair techniques for damage to these pipes includes replacement, grinding out and recoating, hot tapping section, steel reinforcement sleeve repair (Type A Sleeve), steel pressure-containing sleeve repair (Type B Sleeve), and composite wrap repair. Internal repair techniques include cement mortar lining systems, epoxy spray lining systems, slip-lining systems, pipe bursting, and cured-in-place pipe (CIPP) liners.

The team looked at a number of environmental factors which can be used to estimate the corrosion rate. Soil corrosion is affected by many parameters including soil resistivity, water content, pH, soluble salts, oxygen concentration, soil chemistry, and microbial activities. Accordingly, corrosion-rate in soil may change along the length of the pipe and it makes it difficult to obtain a single rate. The estimation of corrosion-rate estimate in a specific pipe segment may be based on the uniform soil or backfill properties that are representative of the segment.

Soil parameters interact together so that each parameter is affected by the contributions of the other ones. The team is developing a simplified approach using a Bayesian Network to assess corrosion growth rates based on soil parameters and environmental conditions around the pipe. The model presents a simplified approach since it adds the effects of the various soil parameters independently. In reality, soil parameters interact together so that a change of a single parameter may affect the contributions of the other ones.

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Specific hydrocarbon permeation effects on PE pipes and corresponding measurement changes in NDE (Non-Destructive Evaluation)

The completed Sustaining Membership Program (SMP) project "Ultrasonic Measurement of HHC (Heavy Hydrocarbon) Permeation Levels in Polyethylene (PE) Pipe" has shown that it is possible to detect HHC permeation in PE pipe using standard ultrasonic sensors. This project builds on this finding.

Project Description

HHC permeation is when hydrocarbons diffuse through a PE pipe wall and typically occurs during heat fusion processes. HHC contamination may degrade the fusion performance, requiring an alternate joining technique to be used. The presence of HHC may go undetected when the electrofusion process is used. In addition to the impact on fusion joints, the HHC can also potentially degrade the strength of the polymer. If this occurs, some pipelines may need to operate at a lower pressure to address the reduced strength of the polymer.

In the prior SMP project, "Field Tool for Detecting HHC Permeation in Polyethylene Gas Distribution Pipe," a portable tool was developed that can be used to non-destructively evaluate pipe in situ for HHC permeation. This project will provide fundamental material property data that is needed for better interpretation of ultrasonic signals taken in the field. Additionally, the material properties obtained will enable the multi-physics simulation of permeation, material softening and swelling, and ultrasonic wave propagation.

Deliverables

The key deliverable for this project is a final report that provides fundamental data regarding specific heavy hydrocarbons diffusion through PE material and describes the resulting impact on material models that simulate HHC permeation in PE piping systems.

Benefits

There are currently no non-destructive tests to measure the level of HHC permeation in polyethylene pipes in the field. Having the ability to detect and measure the percent permeation with a field deployable, non-destructive evaluation method will be advantageous to operators.

The information gathered in this project can be fed directly into risk models to help assess the potential impacts of the HHC permeation on the polyethylene distribution system. Operators will be able to track the ingress of HHC into the system and better understand which gas supply sources are introducing the HHC into the system. The method will also allow operators to detect HHC permeation before cutting into pipe and thereby help determine the most effective joining method ahead of time.

The material property data obtained in this project will provide a needed reference for ultrasonic signal interpretation. This reference data is required because determination of HHC permeation is based on comparing the signal in a field measurement to a signal taken from the corresponding new material. The data obtained will quantify the diffusion rate of specific hydrocarbons, enabling operators to understand the transient nature of HHC permeation based on the HHC mixtures in their system.

Technical Concept & Approach

The following is the scope of this project:

Construction of Linear Permeation Test Rigs

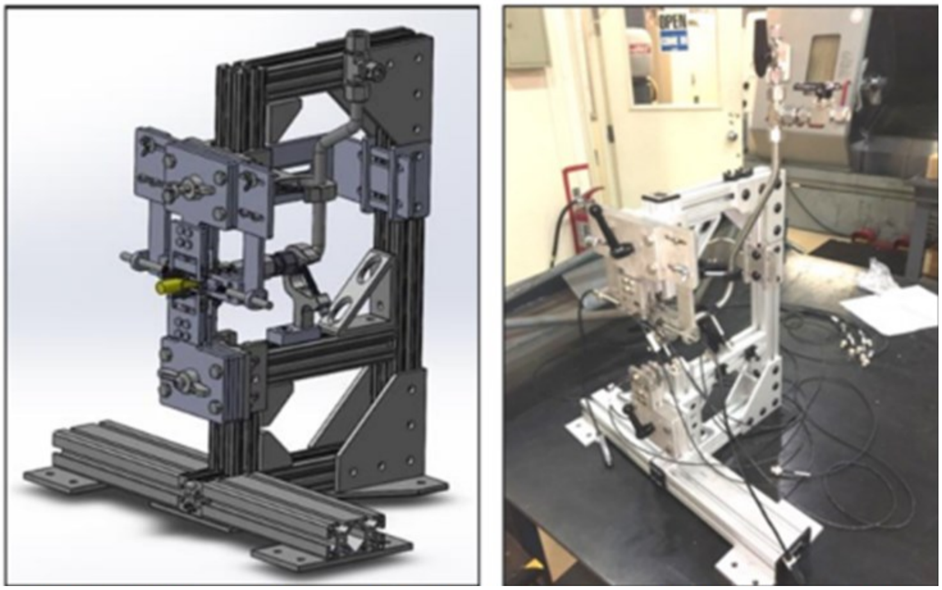
Two linear permeation test rigs will be constructed to pair with a previously developed rig to perform simultaneous testing of hydrocarbon saturated specimens. Previous work has produced a design model for permeation.

Design and Build Test Grips for Mechanical Testing

The specialized mechanical grips required for material testing of saturated samples will be designed and built under this project task.

Prepare Specimens from medium density PE (MDPE), bimodal MDPE, and high-density PE (HDPE) pipe

Specimens will be prepared alongside three separate mixtures of hydrocarbons (C6, C8, and C10). These mixtures will be applied to all PE types for comprehensive testing.



Permeation rig developed and constructed previously.

Run Permeation Tests

PE specimens will be saturated with mixtures of hydrocarbons specified above. Full saturation at room temperature will take 30 days for each sample. Three permeation rigs will expedite full saturation of all samples.

Run Mechanical Tests

Tests will be performed to obtain the mechanical performance of the materials under unsaturated and fully saturated conditions. These tests will quantify the softening effect of saturation across a wide strain (elongation) range. The quantification of the softening effect across a wide strain range will further supplement softening information obtained from ultrasonic signals, which only probe a very low strain range.

Develop Material Property Database & Perform Ultrasonic Signal Modeling

GTI Energy will develop a database based on the material properties of the tested PE pipe/ hydrocarbon mixture. This will serve to refine the signal modeling and capabilities of the NDE field tool. An ultrasonic signal model will be developed and better enhance the detection of specific hydrocarbon permeation.

Results/Status

In 2023, the test rig required hardware was purchased and framing was constructed. Assembly of one of the parallel test rigs was completed, including the integration of the ultrasonic sensors and related parts components. After assembly of the test rig and integration of all components, the project team will focus on initiating and debugging the testing software.

The project team continues designing and building the test grips required for conducting the mechanical testing. Specialized mechanical grips are required for material testing of saturated samples.

The project team is focusing on completing assembly of the final test rig and simultaneously validating the testing software operation. Additionally, specimens will be prepared alongside three separate hydrocarbons (C6, C8, and C10). These hydrocarbons will be applied to all PE types for comprehensive testing.

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Gas Service Regulator Vent Field Study

Researchers will quantify natural gas volumes emitted from the vent of residential, commercial, and industrial gas regulators and compare relief valve technologies in order to inform utilities efforts to reduce methane emissions.

Project Description

Traditional gas service regulators are designed with an internal relief valve (IRV), a device that helps maintain pressure by venting small quantities of gas when a pressure increase is detected. Several of the gas service regulators in service currently include IRV and have an emission footprint. Newer dual-diaphragm, vent-limited regulators claim to address this issue by emitting less.

The goal of this project is to quantify natural gas volumes emitted from the vent of residential, commercial, and industrial gas regulators and compare emission rates of traditional internal relief valves (IRVs) and dual stage vent limited regulators during normal operation. The team will track and characterize emission events for different gas demand cases, such as high population density buildings and commercial/industrial utilization.

This Phase 1 effort will focus on the development of an instrument that can be deployed to quantify the number of times the equipment vents to atmosphere and the volume of gas released each time.

Deliverables

Deliverables For phase 1, the team will deliver a functional prototype of the sensor assembly for use with residential gas service regulators to measure releases, and submit a final report of these findings.

Benefits

ILimited data is available on operational releases from regulator and relief vents as a result of challenges in predicting the frequency of venting events, along with the volume emitted each time venting occurs. This project will provide a better understanding of the volume of gas released and develop a device to measure/quantify these releases. The device to be developed in this initial phase will allow pipeline operators/utilities to establish a baseline of the volume of gas being released from these assets. The information developed can be used to capture the decrease in the volume of gas released as these assets are replaced over time.

Technical Concept & Approach

Specific tasks for this project include:

Sensor Selection and Prototype Design

Develop system requirements and functional design, select the sensors, determine the battery power requirements, develop the mechanical design

Development of Prototype and Internal Testing

Prototype the housing, develop data logging and logic, develop the embedded firmware, develop the modifications needed for use with higher capacity regulators, Test the IRV and vent limited regulators with both air and live gas in the laboratory.

Results/Status

The project kicked off in Q3 2023 and the team has ordered and received all main sensors. In the fourth quarter of 2023, the project team acquired the I2C communication protocol required for data acquisition from the Sensirion flow meter and designed the housing assembly. The project team also programmed the data logger to acquire data from the Sensirion flow meter. Testing is already underway and the final report is anticipated to be done in 2024.

The team is currently working through establishing communication between the flow meter and the data logger.

For more information:

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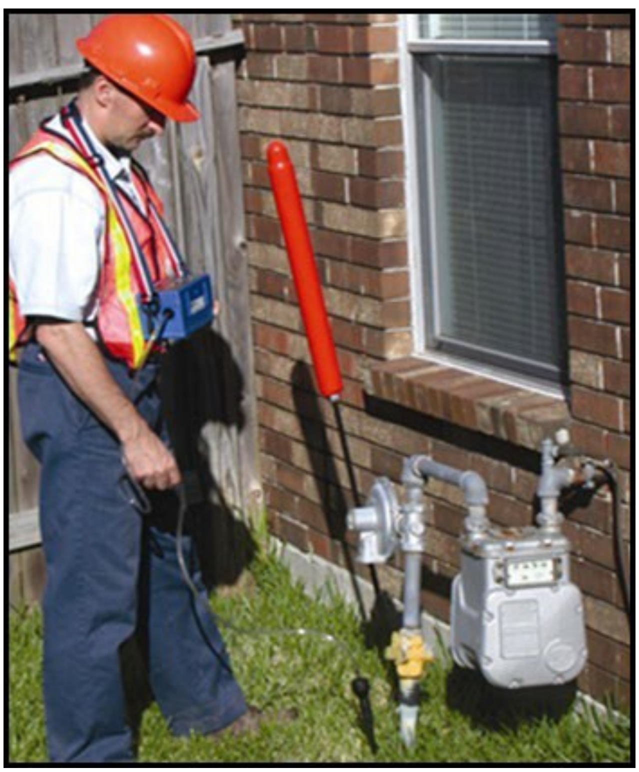
Advanced/Outside Natural Gas Leak Detector

Researchers will develop an Advanced/Outside Natural Gas Leak Detector (ONGD)) that can discover a leak sooner than conventional means reducing risks to buildings and their occupants.

Project Description

OTD has performed extensive work on the development and testing of Residential Methane Detectors (RMD or NGD) that can provide a warning to both the customer and the gas utility of a potential leak. Early detection can play a pivotal role in preventing leaks from growing/migrating, and potentially creating a hazardous environment or resulting in an incident.

The goal of this project is to develop an Advanced/Outside Natural Gas Leak Detector (ONGD)) that can discover a leak before being found through traditional means, such as by an odor call or scheduled leak survey, reducing risk and improving safety. This project will work with industry subject matter experts and manufacturers on the development of an Advanced ONGD prototype that can be attached to the Meter Set Assembly (MSA) piping. The prototype device will be installed at a pipe farm and tested during various weather conditions and various concentrations of natural gas.



Deliverables

The deliverables of this project will include a table outlining the proposed advanced ONGD specifications, a project test plan outlining how the ONGD will be tested, a functioning prototype for testing purposes, and a final report documenting project activities, prototype testing results, conclusions, and recommendations.

Benefits

Outside natural gas leaks can migrate underground and have the potential to find a path into a building or a confined space leading to a hazardous condition. Quicker notification of an outside leak allows more time for a gas utility employee/ contractor to be dispatched to perform a leak investigation and prevent any serious escalation of the gas into a building or a confined space.

The ability to discover and be notified of an outside gas leak using a stationary outside methane sensor will provide quicker detectability as compared to the current processes of leak notification. Early detection is key for safety, improved effectiveness and reduced costs associated with an emergency.

Manufacturers and vendors in the leak detection market offer multiple types of equipment and solutions to perform the federal requirement of leak

survey over gas facilities. Since natural gas incidents still occur after these leak surveys are performed, and additional layer of leak detection that can provide continuous (24 hour) surveillance to detect and notify of leaks will further improve safety.

There is a demand and recent technology opportunity to develop an Advanced ONGD since there have been current advancements in methane sensors that have focused on low-power (for long life battery use), high accuracy (no false positives), improved detectability (for higher ppm) and improved durability to environment conditions (allow for long-life in an outside environment). Many of the newer methane sensors on the market are significantly more advanced that previous sensors and this offers an opportunity to develop a product that will make the natural gas industry safer.

Technical Concept & Approach

The project team will work with industry subject matter experts to define the prototype criteria and specifications. Additionally, a market study will be performed to identify each advanced ONGD component with a focus on the methane sensor. The results will be summarized into a test plan that will be approved by stakeholders.

The project team will develop blueprint drawings, purchase components and assemble a prototype. The prototype will be tested in accordance with the approved test plan.

Results/Status

Prototypes have been sent to GTI Energy for testing. The project team has created a test plan to review with project sponsors. In 2024 the project team will be working to complete prototype specifications and begin development of the prototype.

For more information:

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Project No. 7.23.d

Effect of H2 On Odorants in Gas Blends

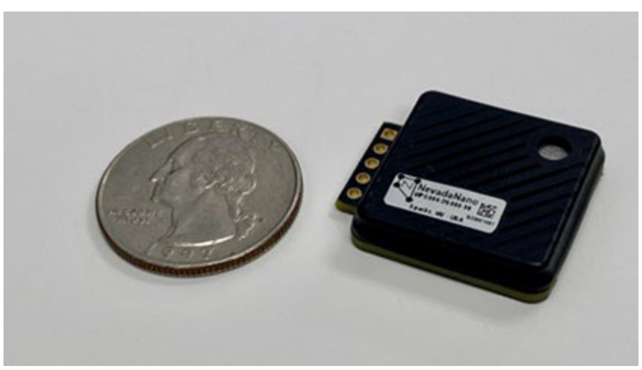
Researchers will determine the impact of hydrogen on odorization to ensure that this safety measure is not degraded through odor fade or preferential leakage.

Project Description

The use of odorants in natural gas distribution systems is the primary means for the general public to be aware of a potential natural gas leak. Adding hydrogen to natural gas can significantly reduce greenhouse gas emissions from gas use and will play a key role in the path to decarbonization, but hydrogen's potential impacts to infrastructure and end use applications (including odorization) have not been thoroughly researched. This project will address open questions regarding hydrogen's impact to odorization so that any issues can be mitigated before the introduction of hydrogen to natural gas distribution systems.

Deliverables

This project will deliver a report highlighting the findings of laboratory experiments, as well as quantitative and qualitative data on the effects of hydrogen in blended gas pipeline leaks.



Nevada Nanotechnology sensor

Benefits

The natural gas industry is committed to delivering a safe and reliable product to its customers. The use of odorants in natural gas distribution systems is the primary means for the general public to be aware of a potential natural gas leak. Adding hydrogen to natural gas can significantly reduce greenhouse gas emissions from gas use and will play a key role in the path to decarbonization, but the impacts of hydrogen on infrastructure and end use applications (including odorization) has not been fully researched.

The odorization of natural gas is the first line of defense for gas users that alerts them to a potentially unsafe condition. Any risk of preferential leakage, or odor fade due to the addition of hydrogen and its effects on odorant concentration/detectability should be carefully understood before the introduction of hydrogen to ensure that this warning system is not degraded.

Technical Concept & Approach

Specific tasks for this project include:

Background Research

Industry and academic research will be reviewed to determine representative laboratory setups for odorant application in hydrogen blending. The setups would be representative of typical leaks in gas distribution, like threading components, couplings, or connections on cast iron. Findings will be presented to the project sponsors to decide the most useful leak setup and test procedures.

Laboratory Evaluation of Leaks

Recreate the selected leak condition determined through background research. Gas blends containing varying concentrations of hydrogen with a known concentration of sulfur-based odorant (TBM or THT) will be obtained and tested in a leak rig. The concentrations of the source gas, as well as the leaked gas will then be measured using instruments, such as a gas chromatograph, to determine whether there is any effect on the ratio of hydrogen to methane or odorant concentration. In addition to the quantitative analysis, the presence or absence of odor will be noted by the experimenter as a secondary confirmation of the presence of odorant. The experimenter will be pre-qualified using a natural gas scratch sniff card each day testing is performed.

Lab Evaluation of Odor Fade

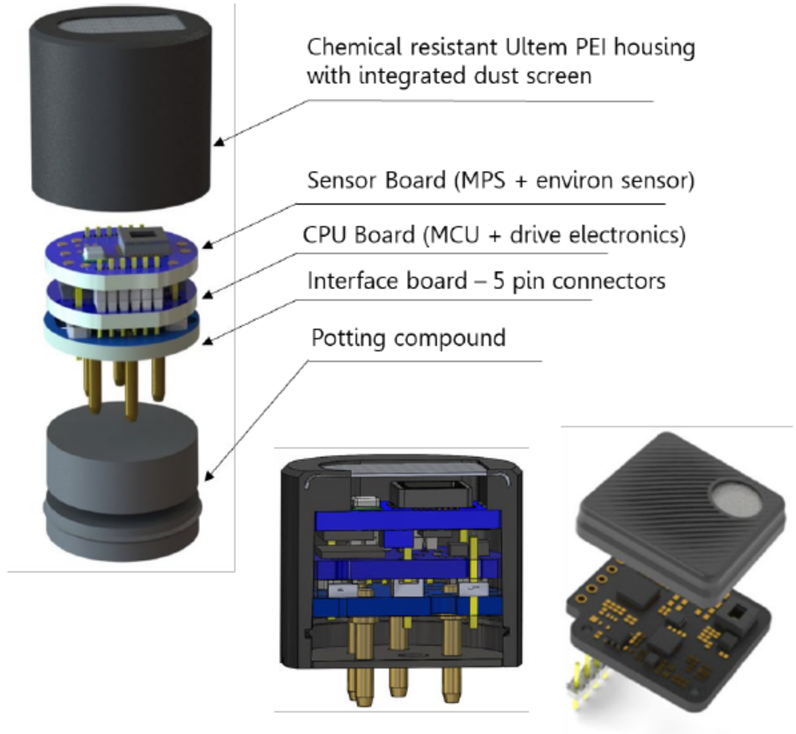
Investigate the effects that varying concentrations of hydrogen blended with natural gas have on odor fade in stagnant pipes. Hydrogen's effect on both THT and TBM will be investigated.

Additional Risks Evaluation

Evaluate findings from white paper studies, as well as results from this project to determine whether further investigation is required for issues related to odorants that may arise in pipelines from the addition of hydrogen and how that research can be conducted and assessed.

Results/Status

The team has selected a supplier and ordered gas standards and a flow meter calibrated for methane. They also completed background research and determined that a pipe diameter of 2" inches and flow rates ranging from 1-60 PSI will be utilized. The team has finalized the testing rig design.



The team will be assembling the test rig, developing methods of GC analysis, and performing trial runs. Upon arrival of the odorant standards, initial samples will be analyzed in order to monitor the effects of odor fade over the duration of the project. Test runs will be performed on the sampling rig, and any previously unanticipated design changes will be made as necessary before beginning the testing designated in the testing schedule.

For more information:

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Net Zero Infrastructure Program (NZIP)

NZIP seeks to equip stakeholders with a holistic understanding of the complexity and value of existing natural gas infrastructure systems, provide a R&D roadmap to address research gaps, and highlight the investments required to ensure today's assets most effectively contribute to tomorrow's net-zero energy's systems.

Project Description

Natural gas is already playing a key role today in providing an affordable, reliable, and low-carbon energy supply to many developed economies. Additionally, natural gas infrastructure will be critical to moving increasingly decarbonized natural gas and other gases, such as renewable natural gas, hydrogen, and carbon dioxide (CO2).

GTI Energy's Net Zero Infrastructure Program (NZIP) accelerates progress toward net zero energy systems with a focus on how to achieve economy-wide decarbonization by maximizing the existing energy infrastructure. NZIP is a multi-year research effort that will give stakeholders better data, realistic cost estimates, actionable insights, and opportunities for increased collaboration while operating from the foundation that integrated net-zero energy systems must be reliable, safe, resilient, sustainable, and affordable.

Deliverables

NZIP Phase 1 deliverables are to develop the R&D Roadmap in the form of a technical report and host the NZIP Annual Infrastructure Forum.

Benefits

NZIP aims to build off existing studies and research, focusing on addressing how integrated energy systems will evolve, and how stakeholders should plan and invest in gas infrastructure throughout the energy transition. NZIP is also an opportunity to build dialogue and collaboration across stakeholders including researchers, investors, operators and asset owners, and local communities.

Technical Concept & Approach

NZIP is divided into three workstreams and has an interactive web portal that houses up-to-date technological and regulatory developments and NZIP related research and webinars.

Gas Infrastructure

- Establish baseline data and identify research gaps for net zero roadmap
- Provide stakeholders with research analysis and data tools to understand how to leverage the existing gas infrastructure to reach/address decarbonization goals.

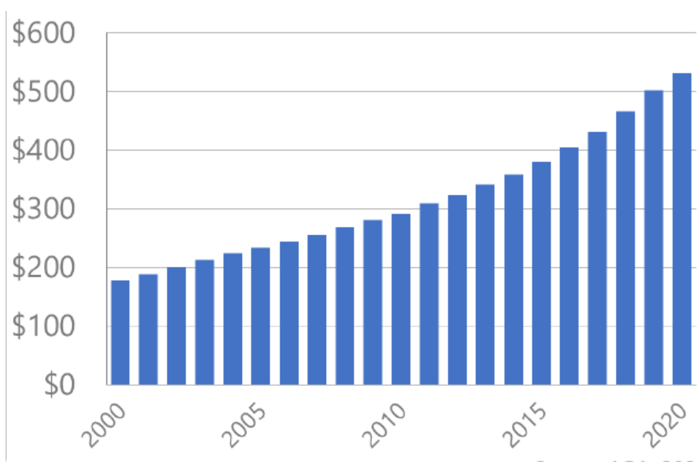
Net Zero Roadmap

- Develop decarbonization roadmap for evolving existing gas infrastructure
- Provide technology overview and R&D roadmap for decarbonization solutions
- Recommendations for how gas infrastructure can accelerate emissions reductions

Policy and Social Impacts

- Provide holistic understanding of broader

Cumulative Investments ($Billions) into Natural Gas Infrastructure



Source: AGA, 2020

societal impacts of gas infrastructure development

- Identify and define policy and regulatory opportunities that could catalyze decarbonization efforts through repurposing gas infrastructure

Results

NZIP has 25 utility and midstream partners from across the country. NZIP has also convened an Advisory Committee comprised of academic experts and stakeholders from the investment and eNGO community that includes JP Morgan Chase, CalSTRS, CATF, Kimmeridge, Bipartisan Policy Center, Rocky Mountain Institute, Environmental Defense Fund, and CERES. The NZIP team continues to share research among partners and stakeholders such as technology solution providers, federal and state policymakers, investors, and utility companies.

In 2023, NZIP published its first whitepaper detailing the vision for evolving the United States' natural gas infrastructure towards a net-zero future.

Status

In 2023 NZIP's executed on Phase 1 deliverables. Results of Phase 1 and ongoing NZIP initiatives can be found at nzip.gti.energy.

In 2024, NZIP will focus on its 2024 goals (Phase 2) to develop regional decarbonization and R&D case studies that assess the role of current and future U.S. gas infrastructure in the energy transition to net-zero emissions by midcentury. OTD members are also participating in NZIP's Phase 2 efforts.

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Project No. 7.23.g

Investigate Feasibility of Pipeline Thermographic Internal Inspection for Leak Detection

Researchers will evaluate a novel in-line pipeline leak detection approach using infrared thermography. Practical tools for timely leak detection enhance safety and reduce methane emissions.

Project Description

Infrared (IR) inspection is a mature technology used in many settings, including optical gas imaging (OGI), thermography, and a host of other research applications. Infrared cameras detect and image temperature differentials. Available examples of infrared inspection are applied externally to the subject, creating an image of varied temperature over the surface of the object.

This project evaluates a novel approach to leak detection using infrared thermography within a pipeline. If feasible, this approach could lead to the development of a tool for inline inspection (ILI). The concept focuses on temperature differentials arising from the Joule-Thomson effect as gas escapes through a leak. As part of this project, computational fluid dynamics (CFD) modeling explored potential temperature differentials over the internal surface of a pipe, with promising results. Lab experimentation will use infrared thermography (camera) to measure observable temperature differentials from within a pipe .

Deliverables

Deliverables include a literature review, results of CFD modeling, and findings of laboratory experiments.

Benefits

Practical tools for timely leak detection enhance safety and reduce methane emissions. If successful, this project could yield a novel approach to IR leak detection with ILI.

Technical Concept & Approach

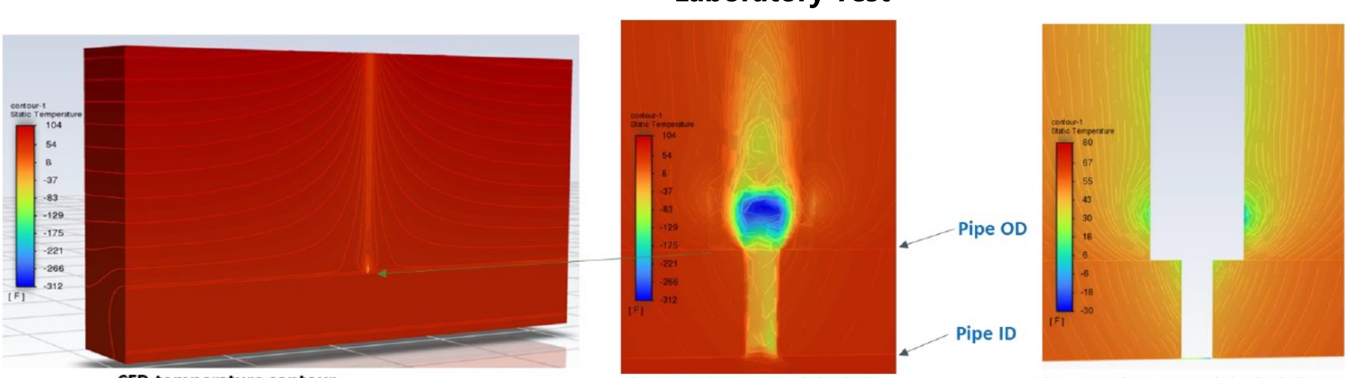
Literature and Product Review

Evaluate prior research and existing technologies that may provide insight for this approach. Conduct a review of IR cameras that may be suitable for the application (size, sensitivity).

Temperature Differential Model

Model the thermodynamic effects due to a gas leak. A simplified, first order Computational Fluid Dynamics (CFD) model was generated to estimate the temperature differentials in the region of the leak.

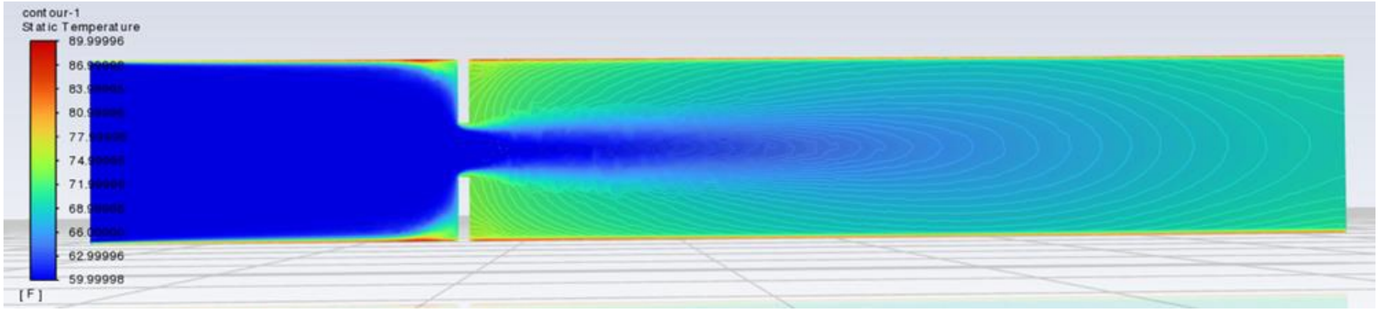
Laboratory Test



CFD temperature contour

Close-up view around the hole

Close-up view around the hole(no gas)



Measure temperature effects on the interior and exterior of a pipe due to a gas leak. A variety of leaks will be created in the experimental setup. IR cameras and other thermocouples will be used to measure temperature differentials in the region of the leak, internally and externally. Results will be compared with the thermal model.

Results

Information has been gathered about available IR cameras potentially suitable for this purpose, and two cameras selected (one internal, one external). IR inspection methods currently in use typically involve the external application of infrared sensing. As such, internal inspection with IR may be a novel approach.

CFD modeling examined steel and plastic (PVD) pipe, at 50-100 psig pressure. This modeling effort revealed a significant temperature difference in the region of the small (1/8-inch) leak. Modeled temperature differentials on the order of 50-300 F should be readily detectable with IR.

Experimental setup is currently in progress, using steel and HDPE pipe and natural gas for testing. Two IR cameras (one external, one internal) will be used to measure temperature differentials.

Status

Experimental setup is currently in progress, using steel and HDPE pipe with natural gas for testing. Two IR cameras (one external, one internal) will be used to measure temperature differentials.

For more information:

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Optical Laser Gas Imager Monitor

Researchers will develop a pilot automated system that supports direct coupling of the inspection and test documentation using a machine-readable identification system, enabling field personal the ability to verify the required inspection and test documents are in the possession of the utility and automatically file inbound documents in the correct location.

Project Description

GeoTeknica is in the early stage of technological development of a novel low-cost, high sensitivity optical gas imager (OGI) for use in continuous monitoring applications. This project will assist with technical guidance and evaluation in development of GeoTeknica's gas imaging technology.

GeoTeknica has invented a new generation of active laser scanning methane imager with the advanced detection capabilities of leading LiDAR systems. GeoTeknica aims to commercialize this technology at a cost advantage that will permit operators to install multiple units at a facility for comprehensive detection coverage. Deployed strategically, this could enable detection without occluded regions, as well as generation of 3D emissions profile by simultaneous detection of leaks from multiple angles.

Software analytical tools are designed to process data and generate a near-real time estimation of methane emissions of a precision currently unattainable with existing technologies. Target applications of this solution include upstream facilities, midstream operations, and high-consequence utility infrastructure.

Deliverables

This project will provide analysis and recommendations on advancing the development of a potentially low-cost/high performance optical gas imager for fixed monitoring applications.

Benefits

Fixed continuous monitoring offers the capability to detect leaks on critical infrastructure as they occur, enabling response before it is discovered by periodic inspections, to reduce risk and emissions. A continuous monitoring instrument that measures emissions with greater sensitivity could detect, locate and quantify smaller leaks quicker, and would potentially reduce leaks and emissions. Potential first applications would be for high consequence transmission lines and M&R stations.

Technical Concept & Approach

This project will seek to provide technical input in development of an alpha prototype and evaluate detection performance. Work will be divided into the following tasks:

Preliminary Design Review

Confer with GeoTeknica as prototype development progresses and provide technical guidance.

Prototype (Laboratory) Testing

Test the prototype instrument in the laboratory. Initial tests will focus on controlled leak rates under indoor controlled conditions better understand detection lower limits. Outdoor testing will focus on establishing detection limits with uncontrolled test conditions such as background, above and below ground.

Gas Town (Field) Testing

Test the prototype in field situations. This will focus on additional data gathering to support the analysis

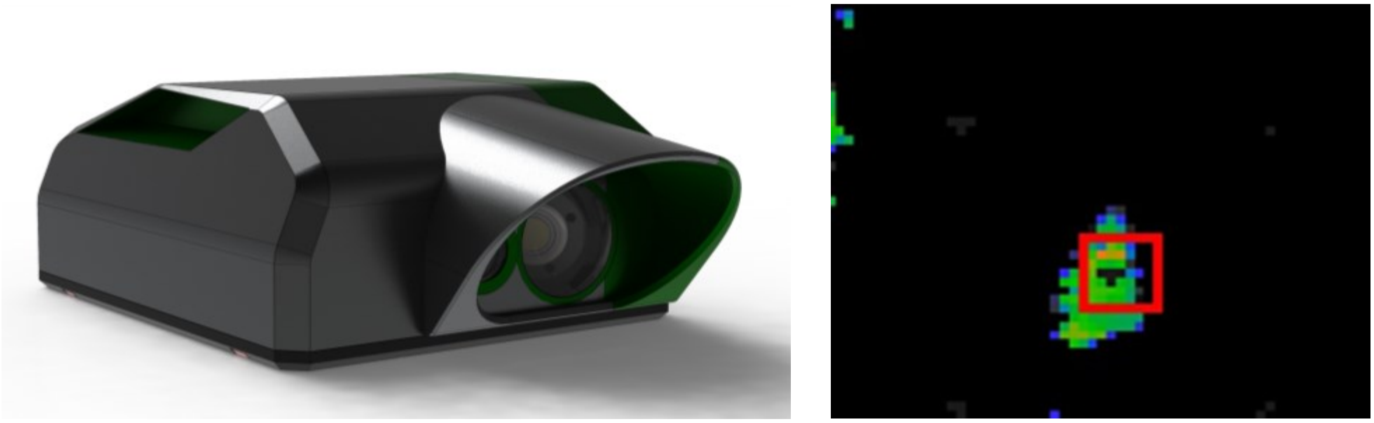

Figure 1 – Instrument Housing and Gas Image using a 1" gas cell with 500 ppm.m concentration

of detection limits. Using an OTD member training facility, data will be collected on the varies leak locations and flow rates over a course of a week.

Results

The project team has been meeting with GeoTeknica to discuss design elements as prototype development advances. A working prototype has been developed, and laboratory testing is in progress at GeoTeknica. Initial results are encouraging. Imaging of the gas plume has been achieved. Figure 1 illustrates the instrument housing and gas plume image created with the prototype instrument.

Status

Good progress has been made in the development of a prototype, and implementation issues related to ancillary components are being addressed. However, Geoteknica has encountered delays in final steps prototype readiness they are working to address. These delays impact scheduling of subsequent testing to occur at GTI Energy and in the field, which will continue into 2025.

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Net Zero Infrastructure Program (NZIP)

NZIP seeks to equip stakeholders with a holistic understanding of the complexity and value of existing natural gas infrastructure systems, provide a R&D roadmap to address research gaps, and highlight the investments required to ensure today's assets most effectively contribute to tomorrow's net-zero energy's systems.

Project Description

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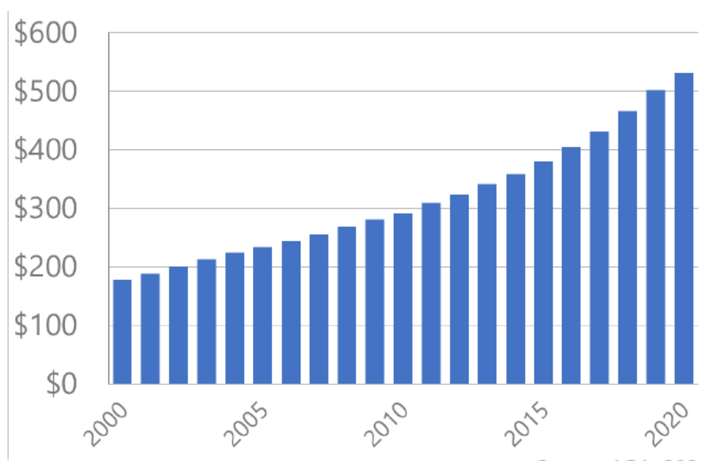
Cumulative Investments ($Billions) into Natural Gas Infrastructure



Source: AGA, 2020

Policy and Social Impacts

- Provide holistic understanding of broader societal impacts of gas infrastructure development
- Identify and define policy and regulatory opportunities that could catalyze decarbonization efforts through repurposing gas infrastructure

Results

NZIP has 25 utility and midstream partners from across the country. NZIP has also convened an Advisory Committee comprised of academic experts and stakeholders from the investment and eNGO community that includes JP Morgan Chase, CalSTRS, CATF, Kimmeridge, Bipartisan Policy Center, Rocky Mountain Institute, Environmental Defense Fund, and CERES. The NZIP team continues to share research among partners and stakeholders such as technology solution providers, federal and state policymakers, investors, and utility companies.

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For more information:

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Renewable Natural Gas (RNG) Workshop and Publication

Researchers engage stakeholders in a dialog on challenges and opportunities of integrating Renewable Natural Gas (RNG) and develop peer-reviewed publication on RNG gas quality related to various feedstocks.

Project Description

This project seeks to engage stakeholders in information exchange about challenges and opportunities for integration of Renewable Natural Gas (RNG) into distribution systems. Through this process, the project will identify issues and obstacles to be addressed for successful integration of RNG and explore technical solutions and market drivers. RNG gas quality is a central focus in this effort, which will also include publication of a peer reviewed paper on RNG gas quality from various feedstocks.

Deliverables

Deliverables for this project include a workshop event, a paper on RNG gas quality, prepared for peer-review and publication, and a final report with information about the workshop and paper.

Benefits

In the drive to decarbonize energy systems, RNG produced from anaerobic digestion or landfill gas are important resources. The character of trace constituents in RNG is related to the feedstock from which it is derived and will differ among source types. Better understanding of these issues and potential solutions are needed for successful integration of RNG resources. This workshop provided a forum of varied perspectives with presentations and dialog to better understand and manage issues of gas quality, upgrading technologies, blending, and project development.

Organic Waste

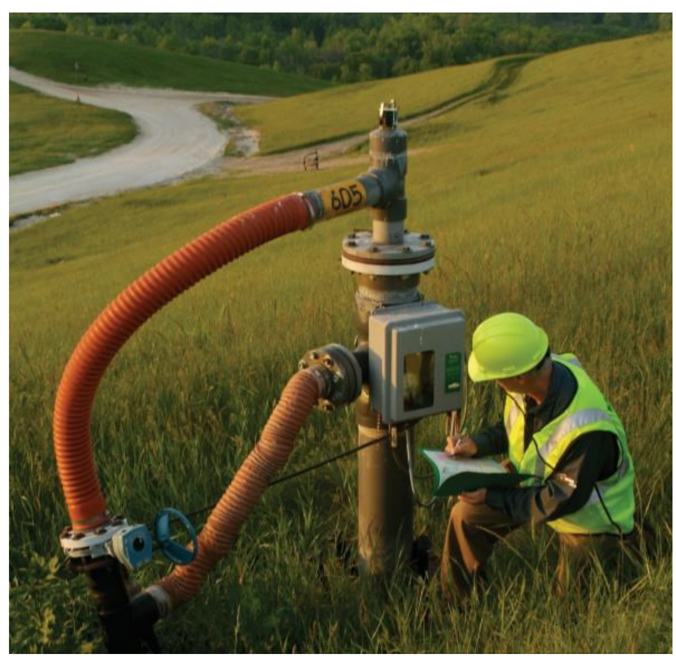
Technical Concept & Approach

Develop Workshop Content

Develop workshop content in a series of meetings with project sponsors, to identify issues of concern and "pain points" or obstacles to greater integration of RNG in distribution systems. Topics included RNG gas quality, blending, upgrading treatment technology, regulatory concerns, and economic factors.

Stakeholder Engagement

Conduct a workshop in order to bring forth varied perspectives which could include utility personnel,



Landfill Gas Collection Wellhead

Dairy Manure Anaerobic Digester

technology purveyors, project developers, environmental groups, and others. To reach these prospective stakeholders, develop marketing materials and disseminate via social media and email campaigns.

Workshop Event

Hold a workshop event for sponsor companies, consultants, and project developers.

Peer-reviewed Paper: RNG Gas Quality

Analyze RNG gas quality data and develop a peer-reviewed whitepaper, building upon the work of OTD project 7.18.b "Biomethane Justification Study for Improved/Accepted Gas Quality Standards". Update graphs and statistics and prepare a document for publication in a peer reviewed journal. Leverage existing data from various OTD and PHMSA sponsored RNG projects to promote the use of RNG as a carbon neutral fuel.

Results/Status

A workshop was held in August 2023, and included participants from utilities, consulting firms, service providers, and other external stakeholders. With the workshop event completed, the team is focused on developing the peer reviewed publication and final report.

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Operations Technology Development

Mercury Action Limits for RNG Specifications

Researchers will develop a plan to test the impact of trace amounts of mercury found in RNG on common materials and equipment found in pipelines and end use products in order to determine safe threshold levels.

Project Description

The goal of this Phase 1 project is to develop a test plan to determine the impact from vapor phase mercury on components and materials found in end use and pipeline distribution equipment. This data can be used to inform the selection of appropriate mercury trigger and action levels for natural gas distribution systems. Phase 2 of the project will execute the test plan developed in Phase 1. Southwest Research Institute is the prime contractor with project management and technical input by GTI Energy.

Mercury is a known trace constituent in both raw biogas, especially raw biogas derived from a landfill and in some natural gas geological formations. Concentrations range from < 1 µg/m3 to >100 µg/m3. If it is present in a sufficient concentration, it is known to promote corrosion of aluminum, copper, and potentially steel alloys used in gas processing, end use equipment, and pipeline materials of construction.

Mercury can corrode by 4 basic mechanisms causing loss of mechanical strength in the affected components, including Amalgamation (formation of liquid solutions or alloys with metals), Amalgam Corrosion (amalgamation in the presence of water), Liquid Metal Embrittlement (stress corrosion cracking through weakening of the intergranular crystalline boundaries by the amalgamation processes), and Galvanic Corrosion (process that occurs when two dissimilar metals are in contact).

California utilities are required by the state public utility commission to establish a trigger, a lower action level (LAL), and an upper action level (UAL) concentration level for mercury in Renewable Natural Gas (RNG). This rule impacts any utility who desires to distribute RNG in California. The trigger level is defined as the concentration above which certain monitoring requirements are enacted. Most constituents in the CA specifications also have a lower action level (LAL) and an upper action level (UAL) concentration assigned. The LAL is a level that if exceeded more than 3 times in any 12-month period would result in a shut-off. Exceeding the UAL results in immediate shut-off.

Currently there is only a mercury trigger level (0.08 mg/m3), and no action limits, resulting in unclear direction if that trigger level is exceeded by a routine gas analysis for mercury. The literature study update conducted by SwRI concluded that while there is plenty of literature focusing on mercury corrosion of materials, very few are directly applicable for mercury corrosion in the natural gas network.

Deliverables

- An updated literature review on the impact of trace amounts of mercury in a gas stream on common materials and equipment found in construction, pipelines, and end use products
- A test plan for lab testing

Benefits

RNG is derived from landfills, Waste Water Treatment Plants (WWTPs), dairy farms, food waste processors, and other sources and will be an important part of the energy decarbonization effort. Anything that limits the introduction of RNG reduces the decarbonization impact of RNG. Mercury is a common contaminant found in RNG. The presence of mercury in gas can promote corrosion but it is unknown at what level this will occur. Upgrading technology for RNG usually successfully removes mercury from the raw biogas but research has not been done to determine threshold levels above which mercury will have to be removed to in order to prevent corrosion of natural gas infrastructure and end use products. The research conducted on this project fills that gap.

Technical Concept & Approach

Literature Review

Assess the previous mercury impact literature review and incorporate any new literature discovered as part of a thorough literature review. Target information regarding mercury impact materials found in infrastructure construction and impacts on equipment like that found in a natural gas distribution network and end use equipment.

Survey OTD Members

Develop a survey document on trace amounts of mercury and distribute it to OTD members. Include topics like respondent's experience, concerns about materials and equipment, recommendations for information sources, and suggestions for a test program. Conduct follow-up communication and interviews as needed.

Test Plan Development

Identify materials/equipment of interest or concern in gas supply containing trace amounts of mercury, based on the literature review and OTD member survey. Recommend test parameters/methods for assessing mercury impact at different concentrations. Review and refine the test plan based on feedback.

Results

The literature review yielded studies on the impact of Mercury corrosion on Aluminum, Steel, Copper, Nickel, Titanium, Cobalt, Bronze, Brass, and Plastic as well as regulations which have been used by various governments to address the risk of corrosion resulting from mercury.

While there is plenty of literature focusing on mercury corrosion of materials discussed above, very few are directly applicable for mercury corrosion in the natural gas distribution network. Only two papers analyzed aluminum and steel samples exposed to natural gas with mercury, where minor corrosion and some mercury accumulation was observed. These papers, as well as the existing international studies and regulations are insufficient to propose guidelines for mercury upper and lower action limits.

The literature review was a useful resource for test plan development. The test setup has been designed to be able to complete tests on a variety of representative materials and equipment from the natural gas distribution network over a wide range of relevant mercury concentrations. The testing results will provide scientific evidence obtained in a well-controlled and documented test program that can inform OTD members and regulators in selecting appropriate mercury trigger and action levels for natural gas distribution networks.

Status

A final report has been released to OTD members and the team is focused on Phase 2 of the project, executing the tests defined in Phase 1.

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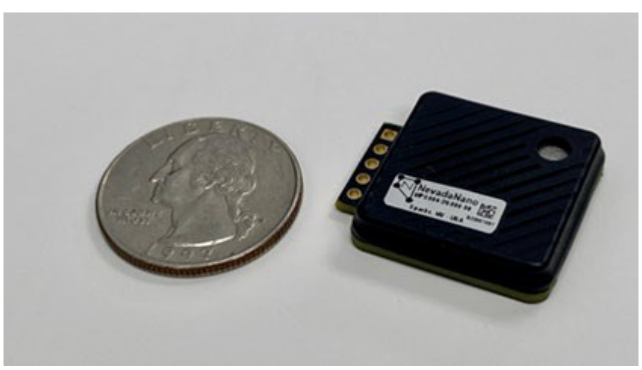
Innovative Gas analyzers for RNG applications

Researchers will evaluate promising technologies and recommend a single online gas quality instrument capable of monitoring essential gas properties and Higher Calorific Value (HCV), in Renewable Natural Gas (RNG). Having one instrument will reduce the cost and complexity of monitoring required to incorporate RNG into natural gas pipelines.

Project Description

The goal of this project is to recommend a single online gas quality instrument capable of monitoring essential gas properties and Higher Calorific Value (HCV), in Renewable Natural Gas (RNG). The considered properties are Wobbe Index, O_2, H_2, H_2S, CO_2, and H_2O. The focus is on prioritizing low-cost technologies, which will be compared to the benchmark of standard online gas chromatographs (GC) used for monitoring geologic natural gas. The recommendation will also include product development roadmaps for each vendor if they are available.

The recent disruptions in gas sensing technology for health and environmental purposes suggest an opportunity for widespread use of sensors in the gas utilities industry. Miniaturized sensors that have already been developed to detect various gases have been integrated into smartphones for monitoring pesticides, ammonia, and noxious gases. It may be possible and beneficial to deploy similar sensors along the extensive U.S. distribution pipelines of natural gas.



Nevada Nanotechnology sensor

This project builds on two past technology assessments: OTD Project 7.16.e focused on detecting trace contaminants in Renewable Natural Gas (RNG), and SMP Project 22284 evaluated emerging technology for monitoring gas quality components and High Calorific Value (HCV) in geologic natural gas.

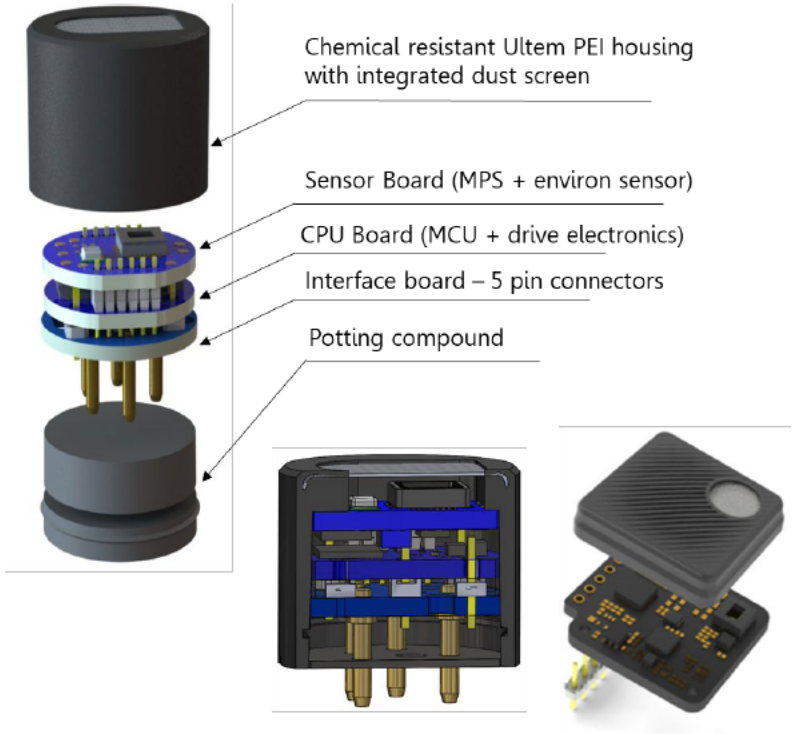
At the time, these projects focused on analytical capabilities for RNG's trace contaminants or gas quality components and HCV in geologic natural gas. The team will reevaluate these detection technologies and update the analysis for use with RNG along with their evaluation of any new technologies entering the market.

By understanding these technologies and engaging in open dialogue with sensor specialists, GTI Energy aims to identify partners and new paths for product development, specifically for monitoring RNG gas quality components and HCV in a single instrument.

Deliverables

Deliverables for this project include an evaluation of emerging and market-ready sensor technologies which can be used to monitor relevant gas properties.

Benefits



The demand for more on-line, remote sensors is still high despite decades of commercially available products. Certain sensors are better equipped to handle different chemical families and specific concentration ranges. In order to detect the full range of relevant chemicals, multiple systems are required for gas quality monitoring. Installing two or more sensors per site is inefficient and requires more maintenance.

Deploying a single unit capable of monitoring HCV and multiple gas quality components at RNG connections provides an advantage by allowing utility companies to pinpoint and respond to fluctuations in gas quality more rapidly.

Technical Concept & Approach

Technology Assessment

Establish minimum performance requirements in coordination with stakeholders. Conduct assessment focusing on current and near-to-market technologies based on the minimum performance requirements established and develop a technology recommendation.

Results/Status

The team has conducted a database review of RNG tariffs to determine the high and low ranges for the analytical parameters in which the instrumentation will be evaluated for this project. Sponsor responses were reviewed, and the final parameters were determined.

The team has held conversations with multiple manufacturers to determine if their instrumentation was feasible for a RNG stream.

This project is complete and a final report has been shared with OTD members.

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Technology for Advanced Natural Gas Detectors

Researchers will evaluate the effectiveness of multiple high-sensitivity gas sensors in detecting multiple types of gases, including a made for purpose prototype developed for this project. These sensors will reduce response times to pipeline leaks including those with hydrogen blends.

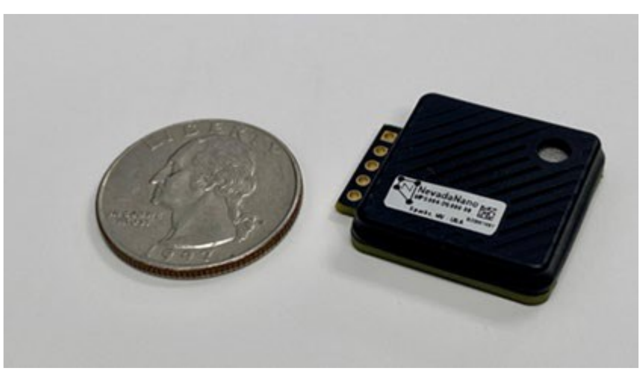
Project Description

Addressing safety concerns in gas distribution systems is crucial, both inside and outside buildings. This project aims to proactively explore sensor advancements for Next-Generation Detection (NGD) technology to stay ahead of potential issues related to gas leaks or emissions. This proactive approach ensures that gas utilities can adapt swiftly and effectively to regulatory changes.

While current NGD devices reliably detect methane at %LEL levels and alert residents in a timely manner, the potential integration of hydrogen into the gas stream and the use of hydrocarbons in refrigerants will require additional capabilities. Industry demand centers on the ability to detect lower gas concentrations, enabling the optimization of NGD device deployment and the provision of precise information to meet evolving industry requirements.

Deliverables

The following deliverables are expected from this project: test data that verifies manufacturer claims for sensor performance, a breadboard test device of a multi-species NGD based on advanced sensor technology, a reference design and projected costs for a production model NGD based on this sensor technology, and an indoor diffusion study based on Computational Fluid Dynamic (CFD) models to determine the required NGD sensitivity versus distance from the appliance or emission source.



Nevada Nanotechnology sensor

Benefits

Safety is the number one priority for gas distribution systems. Gas leaks, whether they occur inside or outside buildings, necessitating a swift response and investigation by gas utilities. The project's objective is to investigate technology for the next generation of Advanced Natural Gas Detector (NGD) devices. It involves exploring sensors capable of detecting multiple gas species or specific gases at lower concentrations with a focus on understanding and addressing the potential challenges presented by the incorporation of hydrogen into the gas stream. This work also contributes to the creation of new industry standards like NFPA 715 "Standard for the Installation of Fuel Gases Detection and Warning Equipment".

Technical Concept & Approach

Investigate Multi-Species Sensor Technology

Collaborate with a sensor technology provider to test a multi-species gas detection (NGD) device, which utilizes a sensor element to classify flammable gases based on molecular weight. Test the breadboard device for gas mixture detection, response time, power consumption, and environmental effects. If results are positive, create a reference design for a commercial NGD using the chosen sensor.

Investigate High-Sensitivity Sensors

Obtain samples of high-sensitivity gas detectors from different manufacturers. Test these detectors for their detection limits and response. Investigate indoor dispersion and plume models to determine required sensitivity levels.

Data Analysis & Reporting

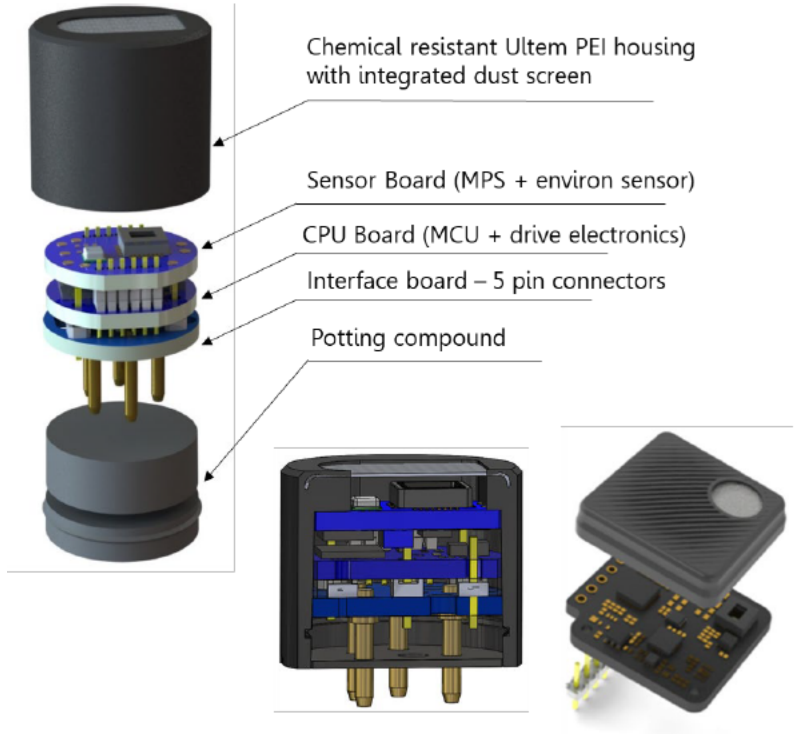
Develop reports using data collected from previous tasks, ensuring reports address current and future developments in the regulatory space.

Results

The team is currently working with two companies that provide sensor technologies. Agreements are in place with both.

Status

The team has acquired samples of multi-species gas detectors that can identify H_2, H_2/ CH_4 blends, CH_4, and heavier hydrocarbons. Samples of high-sensitivity (50-100ppm noise floor) sensors have also been acquired. The details of the testing plan are being worked out.



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Satellite Methane Detection for Distribution Applications

Researchers will evaluate new technologies in the market for software solutions for satellite detection of methane leaks to determine if they be a tool for operators to consider for monitoring their distribution systems.

Project Description

This project seeks to evaluate the new orbital methane sensing products claiming to provide significantly more sensitive detection of methane emissions than those previously studied. The study will focus on LDCs applications for leak detection, localization, and/or quantification.

In the past, use of satellite-based methane detection technology has been somewhat effective, mainly in the upstream oil and natural gas segments (e.g., production, processing). Two recent studies have pointed to the usefulness and limitations satellites. One study published in March 2023 in Nature (Sherwin et al. 2023), shows that current satellite technology was only able to capture emissions down to 0.20 tons per hour range (9,450 cubic feet per hour). The study used a standard release rate of 4 tons per hour to test. Even at these high rates of release the satellites did not detect the releases 100% of the time.

A review by Jacob et al. 2022 of satellite technologies indicates that satellite detection thresholds are in the 100 – 10,000 kg per hour range (5,210 to 521,000 cfh). At these levels of detection, the applicability to distribution appears to be quite limited. Numerous competitors have entered the market in recent years with claims of their product's effectiveness. Some of these companies even claim to be able to infer leaks on a distribution level (< 1 kg/hr) using AI and advanced geospatial analytics software.

Deliverables

Deliverables for this project will include a literature review to better understand the technologies of new market entrants, a test matrix developed to evaluate these technologies, Test results, and a final report.

Benefits

Using satellites to enhance leak surveying is adds benefits to how a LDC's is operate and maintain the pipelines, however, satellite technology might need to be further developed to provide the type of information needed for this use case. This project seeks to evaluate technical aspects and cost-effectiveness of new state-of-the-art products as a useful tool in detecting leaks.

Technical Concept & Approach

Literature Review and Academic Feedback

Review currently published work on satellite evaluation for methane detection. Understand the potential detection improvements of new systems that are proposed or currently coming online. Survey academic/technical experts on the fundamentals of the current state of the technology. Understand the crucial variables to satellite-based detection. Define what needs to be better understood with respect to applications for distribution systems.

Field-Testing Logistics and Test Matrix Design

Work with sponsor companies to understand concerns, questions, and experience with satellite leak detection. Identify test opportunities with sponsors and develop a plan for field testing and ground truthing of satellite data. If desired by the sponsors, work with satellite provider(s) in

Urban domain methane measured in parts per million and flow rates in kg/hour

Measuring both plume and flow rates using Satelytics' algorithms – source of leak marked with alert symbols chosen by customer

The meter has a small leak 200 ppmXm below the insulated union

development of the test plan. Develop a statistical/analytical approach for the large amounts of data to be collected.

Go/No Go

Based on the information gathered in the early project and sponsor feedback, determine if field deployment is warranted. Coordinate with sponsors for field testing in coordination with upcoming satellite capture events. With sponsor engagement, planning is underway at this time.

Field Deployment

Conduct two targeted field deployments to evaluate satellite technology with appropriate follow-up surveys in selected environments. Deployment will include implementation of the test matrix, verification of leak rate on a subset of leaks.

Data Analysis

The amount of data collected will likely be extensive. Data from satellite captures will be evaluated for true detection results and false detection results. This evaluation will also examine if the leak source is correctly identified (e.g., gas facility vs swamp/production/industrial/agricultural), and factors related to conditions at the time of survey.

Results/Status

Following kickoff in Q3 2023, sponsor meetings explored questions about the application of satellite technology for methane leak detection. Sponsors shared demonstration experiences with a company marketing satellite methane leak detection for distribution applications. Multiple project sponsors have conducted or are conducting demonstrations with the selected distributor and may be willing to share this information for the purposes of this project. Such data sharing would provide a greater volume of information, sufficiently controlled and aggregated, on which to perform analyses. The project team seeks to explore information from these demonstrations to produce an overview of satellite technology in distribution applications. These early discussions with sponsors also suggest an opportunity to support ongoing or planned demonstrations by providing test plans and experimental design support. The team also consulted Dr. Joe von Fischer of Colorado State University to provide support and academic review.

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Project No. 7.23.o

Methane Detection Technology – Regulation Equivalence Testing

Researchers will develop a protocol to evaluate leak detection technologies on a common benchmark, highlighting functional differences and comparing effectiveness.

Project Description

A considerable amount of commercially available technologies exist for detecting methane leaks, including flame ionization detection (FID)-based instruments, infrared (IR) gas detectors, or tunable diode laser absorption spectroscopy (TDLAS) devices. Various products exist in each category and their features and specifications can vary. With new leak survey and detection tools continuously coming to market, it can be difficult to identify the operational differences compared to existing technologies.

The goal of this project is to develop a protocol to evaluate leak detection technologies on a common benchmark, highlighting functional differences and comparing effectiveness. Equivalence testing of various technologies will provide an understanding of relative detection effectiveness and performance of various technologies. The protocol will aim to be technology agnostic.

Deliverables

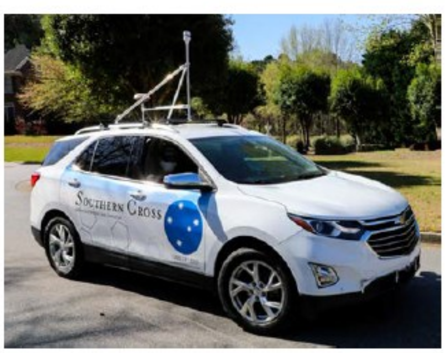
The deliverable for this project will be a protocol to evaluate leak detection technologies on a common benchmark.

Benefits

Continuous advancement in the leak detection market has inundated the industry with products of varied function and outputs with operational differences that can be ambiguous. A testing protocol developed for a consistent benchmark would seek to remove the external variables and focus on the effectiveness of each technology to complete a specific task.

Picarro Surveyor

Heath Consultants AMLD



Southern Cross AMLD

Mobile methane detection technologies in the field

This benchmark will allow easier comparison between technologies. Using this benchmark, the list of products that meet acceptability criteria can be expanded, allowing operators to use the most effective tools and providing flexibility in choosing the right tool for the situation.

Technical Concept & Approach

Review Technical Documentation

Review available comparison studies and test data from previous Advanced Mobile Leak Detection (AMLD) projects.

Protocol Development

Develop a preliminary protocol framework that provides guidelines on testing various technologies and on conducting comparisons between technologies.

Alpha Testing of Protocol

Perform benchmarking of protocols on AMLD technologies.

Results/Status

The team selected four AMLD technologies for inclusion in the technical documentation review and relevant product information has been collected. A literature review was conducted to find any available comparison studies or test data for these products. The team also researched the minimum requirements and approval process for using an alternative technology for distribution leak surveys at the federal level and for the state of New York. The results of these reviews will inform the protocol development.

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Renewable Natural Gas Technology Convergence White Paper

Researchers will explore how key renewable natural gas (RNG) technology pathways converge to exploit their respective advantages.

Project Description

Renewable Natural Gas is associated with four main technology pathways: anerobic digestion, gasification, pyrolysis, and power to gas (PtG). While anaerobic digestion currently dominates the RNG market, PtG, pyroloysis, and gasification represent important potential growth sectors for RNG. Interest in these alternative pathways arises in unique areas of application for PtG and gasification.

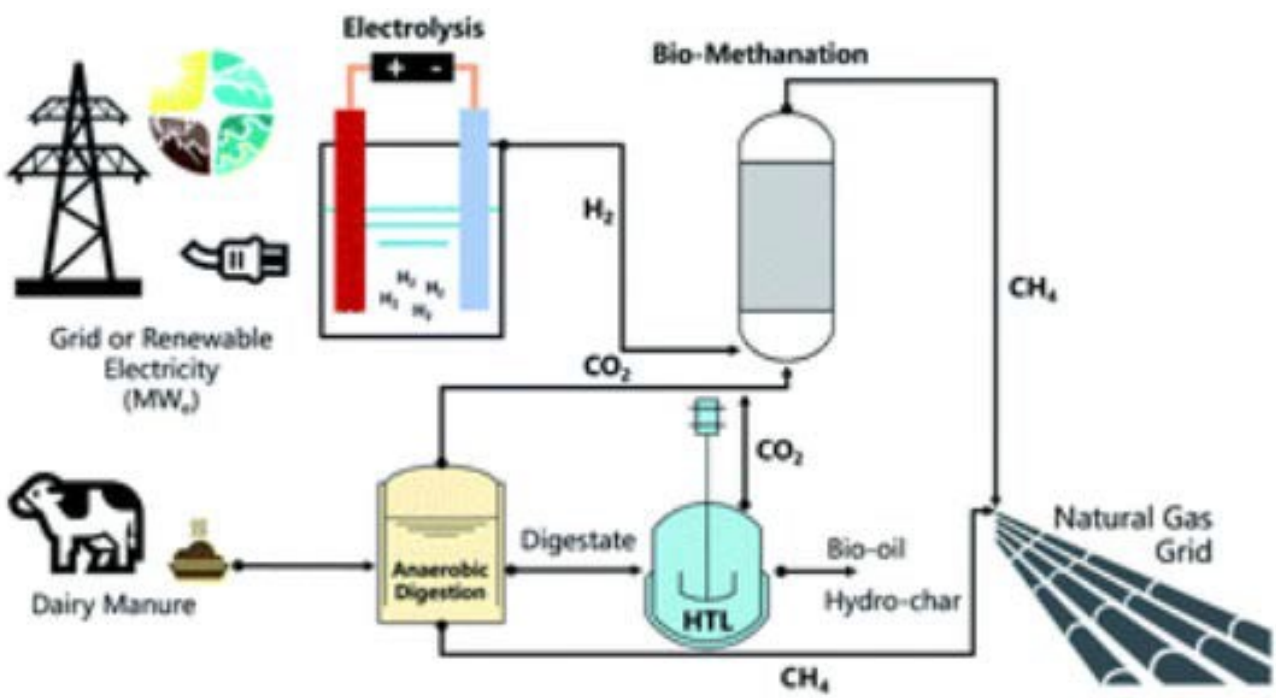
This project seeks to explore key renewable natural gas (RNG) technology pathways and their respective advantages in relation to others. It will examine where different RNG technologies bring greatest value and whether optimized noncompeting or complementary applications exist among the technologies. Considerations in understanding the different pathways include feedstocks, associated infrastructure, biogas yield efficiency, fuel end use, scalability, interconnection considerations, and where RNG pathways fit in the electricity generation market.

Deliverables

A report summarizing the findings from the analysis which outlines the benefits of each pathway will be provided.

Benefits

This work directly supports decarbonization efforts by addressing knowledge gaps surrounding different RNG technology pathways and potential benefits of



Combined PtG (Electrolysis) and anaerobic digestion optimizing applications. The RNG industry is at a stage of accelerated growth. With the emergence of renewable fuels such as hydrogen and sustainable aviation fuels, there has been growing interest in gasification and power to gas (PtG), which, if generated from renewable electricity, has been identified as a further decarbonized RNG pathway. As such, there is a need to consider the integration of these technologies in the RNG market.

Technical Concept & Approach

Information Gathering

Leverage existing knowledge on usage, scalability, general requirements of the four technology pathways. Review research surrounding anaerobic digester retrofits with complementary adjunct technologies, including gasification, pyrolysis, and PtG.

Synthesis of Findings

Outline usage, scalability, with support of existing knowledge. Identify feasibility considerations with hybrid designed biomass facilities.

Results/Status

Information about the four major RNG technology pathways and respective advantages and applications has been gathered, including aspects of feedstock availability, technology readiness, biogas yield efficiency, and scalability. This work also examines integration with electricity infrastructure, and end use areas of highest precedence for each pathway. Synthesis of findings and preparation of the final report are in progress.

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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.

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T&T – Component Counterfeit Detection, Two Way Product Communication Using GS1 Standards

Researchers are building a component tracking and communication system to verify the authenticity of components, ensuring that faulty counterfeit components do not make their way into the natural gas system.

Project Description

As global supply chains have increased the complexity in verifying authenticity of products and supported by documentation. Industry experience has documented numerous examples of falsified material test reports and open trading introduces many opportunities to introduce poor quality and counterfeit products with fraudulent material test reports.

The goal of this project is to develop processes to screen natural gas piping system components for counterfeits. This will include developing mobile system software for communicating quality control concerns of piping system components directly with the component manufacturer in near real-time.

Deliverables

Deliverables for this project include a prototype demonstration of the system's ability to detect counterfeit components with map-based reporting, a narrative of the requirements to deploy the system for commercial operation, and a final report.

Benefits

Counterfeited components used to construct natural gas delivery systems may pass initial hydro testing but fail a few years into service. Counterfeit components are a growing safety concern, and due to underground construction, finding and removing counterfeit piping system components is a complex and costly to remedy. The industry needs tools to scrutinize products used in natural gas piping systems to ensure that they are authentic and that the components are supplied with quality control test reports that are representative of the components received for use. The processes to ensure authenticity and support tracking and traceability and be able to detect counterfeit components prior to a products incorporation into service.

This project provides a process to assist utilities in screening components for counterfeit materials introduced in open supply chain trading. It provides utilities with a direct channel of communication to a manufacturer who supplies components for utilities through a dealer and supplier network. This project can be valuable where several tiers of suppliers obscure the identity of manufacturers due to acquisitions, stacking of multi-tiered trading partners or multi-level manufacturing organizations, where the manufacturing facility could be one of many locations throughout the world.

Technical Concept & Approach

Tasks for this project include:

Develop System Use Cases

Design the different use cases for executing the processes to detect counterfeit products and report quality concerns to be addressed by the manufacturer.

Integrate Component Scanning Processes for Data Sampling

Develop process software to call existing scanning software to sample components during a receiving inspection process, preinstallation process, or mapping process prior to backfill. Develop process to check for registration of components, spatial registration, assessment of component for its uniqueness, and process any quality concerns by delivering a detailed report of any problems directly to a manufacturer.

Build and Execute Protype System for Demonstration

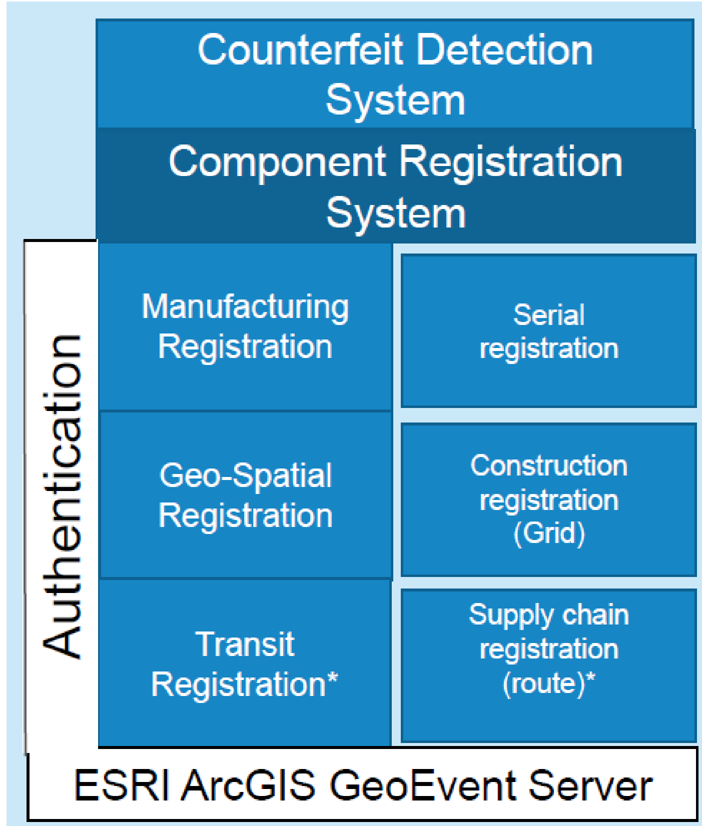
Use real components to simulate and test the processes created and designed in previous tasks and verify that the entire system is capable of detecting and notifying a manufacturer that their products have been counterfeited or that there are components received with quality problems from manufacturing, shipping damage, or other defects.

Results/Status

The team built a new type of communications system allowing a field engineer, material handling/inspection personnel, or office technician the ability to communicate with detailed track and traceability identification information found on a component in a barcode or RFID. The communication process, once initiated, can be completed directly with the manufacturer or brand owner in under 8 minutes. For this process to operate, the information is generated with either a single scan of a product's barcode or execution of a procedure against a utility component installed in a GISbased system that incorporated GS1 standard identification information as part of its documentation. The project takes advantage of the routing facilities of GS1 GDSN services to deliver the information to the manufacturer or departments inside a manufacturing company. This capability has been demonstrated for the last two years using ScanMaster GDSN.

The team completed the initial integration of the GNSS data with the newest version of the iOS application designed to scan 2D barcodes in the first quarter of 2021. The team further developed the iOS application to integrate both barcode information and product information from the GS1 GDSN services system and storing the Geospatial data and product attribute data in a non-SQL database, MongoDB.

The team also developed data storage



processes that are synchronized from the phone to the database and user interface design to build the concept of a data collection project (storing all scanned records and identifying them under a named project.

The data to run the proof of concept task for this project was collected on a pilot project with Dominion of Ohio during Q3 of 2023 as well. Discussions with ESRI took place, and alternate solutions were researched by GTI Energy to complete the development of the prototype.

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GNSS Smart Automations for Field Data Collection, Phase 3

Researchers are developing a new technology which improves geographic data quality and consistency.

Project Description

The goal of this project is to increase the quality and consistency of location data collected using Global Navigation Satellite System (GNSS) receivers by automating certain steps of the collection process and reducing the burden on field data collection personnel. This project is creating a new technology helps ensure consistency and verifies that quality thresholds are satisfied. Additionally, the technology improves the collection process, enabling the field data collector to operate and handle fewer components during any given step.

Phase 3 will improve the existing features of the system and add additional features such as an option for an on-board RTK-capable GNSS chip. Integrating the chip with the unit will eliminate the need for a separate GNSS device.

Deliverables

The project deliverables will include prototype hardware and software, requirements analysis documentation, design documentation, test cases and test case results, an on-site demonstration, a GIS week presentation, and a final report.

Benefits

Often, it is necessary to pair field data with high quality geographic data suitable for map making. GTI's research into GNSS devices and accuracy shows that the best predictors of quality are the capabilities of the hardware device itself and the techniques and practices used by the field data collector. Standardizing the collection process through automation can increase the accuracy of the GNSS position. The device constructed in this project may also provide a cost-effective alternative technology for operators to consider.

Technical Concept & Approach

Requirements Analysis for Additional Functions

Collect requirements for features to be added to the tool. This documentation will guide the follow-on development activities to a successful conclusion.

General Design and Development

Update design documentation to reflect design and development activities which will be conducted in this phase. Build a set of third generation prototype units according to the updated requirements.

Hardware Design, Development and MFi (iOS) Certification

Update the computer board or design a custom computer board which can support iOS integration on-board without the need of the AMAN NMEA-BT by integrating MFi certified Bluetooth technology into the circuitry. Port the current software code to the new environment.

Stand Alone RTK Variant Design and Development

Create a version of the prototype which includes a uBlox ZED-F9P GNSS positioning chip and external antenna connection capabilities.

Investigate All-in-one GNSS Device Integration

Investigate the possibility of using the GSA device with all-in-one data collection platforms which integrates the GNSS hardware into the data collection device.

Prototype Testing and Re-work

Create test case documentation based on the

Phase 3 final prototype

requirements and design documentation. Execute each test case multiple times and record the results. Re-work the prototype to address failed tests.

Commercialization

Identify possible commercialization pathways. Consider options for licensing the original variant, stand-alone variant, and software only variant.

Results/Status

The team made the following improvements to the device in this phase:

Computing Hardware

A color touchscreen display was added to provide a better user interface and experience when interacting with the device and a dedicated Bluetooth module was integrated, potentially allowing for a broader range of devices to be connected. The traditional Raspberry Pi 3, was replaced by the Raspberry Pi Compute Module. The Compute Module is a streamlined version of the Raspberry Pi 3, containing the same processor, but significantly reducing the size of the printed circuit board (PCB) on which it’s mounted, making it ideal for high-density builds. The Compute Module runs the GSA software. Various smaller subsystems were upgraded and or included such as the battery, a USB 2 hub controller, and the inertial measurement unit (IMU). A custom PCB was developed to integrate all the individual subsystems together into a single device.

Software

Two final prototypes of the GSA were printed and fully assembled. Most of the software changes were made because of the hardware changes introduced in this phase of the project such as changes to the display, the inertial measurement unit (IMU), and Bluetooth hardware.

Due to the challenges discovered while trying to meet the requirement of having the GSA communicate via Bluetooth with iOS devices without the need for third-party party hardware, some requirements were not implemented. These requirements include the “Blocking option”, “Make it easier to identify "false" locks so that undesirable positions aren't collected”, and the elimination of the third-party hardware for Bluetooth communication with iOS devices.

The new display allows for much more flexibility in the display of information but also requires a more sophisticated approach to its programming.

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Project No. 8.17.d.3

Low-Cost RTK

Researchers sought to explore the capabilities of the Emlid Reach RS2 Low-Cost Real-Time Kinematic (RTK) GNSS device to be used with LocusView's software and RTK network infrastructure, but were unable to overcome technical limitations.

Project Description

The main objective of this project is to test and demonstrate the capabilities of low-cost Real-Time Kinematic (RTK) Global Navigation Satellite System (GNSS) technologies that can produce centimeter-level precision and accurate location estimates.

Extensive testing of the Reach RS2 system was performed in Phase 2 two of the project. The Reach RS2 reached high levels of accuracy and showed stable performance. Overall, the Reach RS2 test results showed improvement in accuracy as compared to their previous Reach RS model.

In Phase 3, the team will explore the capabilities of the Emlid Reach RS2 Low-Cost Real-Time Kinematic (RTK) GNSS device to be used with LocusView's (LVS) software and RTK network infrastructure.

Deliverables

Deliverables for this project will include a workflow for the use of the Reach RS2 system as a base station within an existing RTK network infrastructure, implementation documentation to help sponsors utilize that integration, and a final report.

Benefits

Gas utility business activities and processes need to achieve safety, reliability and compliancy goals, and as such either produce and/or rely on high-quality data. Achieving these goals at a lower cost would contribute to the efficiency of the organization. The gas industry uses more high-quality GNSS technology, so it is in the interest of gas utilities to lower the per-user cost of such systems so that achieving high-quality data is economically feasible.

Technical Concept & Approach

Tasks for this project will include:

Requirements Analysis (Go/No-Go)

Gather requirements and determine which integrations between the Reach RS 2 system and the LVS system deployments are likely to work. Report these findings back to project funders to discuss whether the project should move forward and what are the most valuable outcomes.

Design and Development

Develop workflow procedures for the use of the Reach RS2 system as a base station in a permanent or a semi-permanent setup within an existing LocusView's RTK network infrastructure. Explore and possibly develop options for using the Reach RS2 with LocusMap software.

Testing and Re-Work

Create test case documentation based on the requirements and design documentation. Execute each test case multiple times and re-work if any problems are identified.

Execute On-Site Demonstration

Schedule one (or more) on-site field demonstrations for participating sponsor (s).

Results/Status

Unfortunately, there were several technical limitations in integrating the tools with the Locusview software, such as the system configuration being complicated from a user experience for a typical field user. The proposed way of managing this issue would require the user to stand next to the receiver with a tablet enabled with the Reach RS2 application, then configure the receiver to send correction data into the LV caster over the tablet's hotspot. This would be required multiple times as the IP address refreshes.

One option from Locusview suggested that troubleshooting with AT&T to see if the units can be set up with Static IP addresses to remote into them from anywhere may solve the issue. Locusview ultimately decided they

were unable to commit to the project due to the low likelihood of success.

As a result, the team recommended canceling the project and returning the remaining funds.

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Corrosion Testing (Longterm Viability) Laser Engraved Barcode

Researchers will develop estimated life of a direct part mark barcode by correlating barcode verifier readings from barcode samples exposed in a salt fog test chamber with actual atmospheric corrosion samples exposed to weathering conditions in Illinois and in Florida.

Project Description

This project will develop estimated life of a direct part mark barcode by correlating barcode verifier readings from barcode samples exposed in a salt fog test chamber with actual atmospheric corrosion samples exposed to weathering conditions in Illinois and in Florida.

Pipe and fittings stored in outdoor storage or equipment operating outdoors is at risk of loss of their identification information. Printed or painted, human readable or machine readable, information is at risk of loss due to sun exposure, erosion, corrosion or other weathering effects. Track and traceability information can be completely lost due to weathering when key identifying information cannot be verified by identification markings on the pipe.

Coating companies try their best to maintain and restore this information over time, but the maintenance processes used to maintain the identity of pipe is contingent on manually maintained logs providing the locations in a storage area of a particular grade, purchase order number and heat identification. Inadvertent movement of this material that is not properly logged risks loss of key track and traceability information if weathering effects render the information, printed on the component for track and traceability, unreadable.

OTD has developed a marking process to dramatically extend the life of identification information on pipe by laser engraving processes developed on OTD Project, Number 8.18.a.2. OTD applied for a provisional patent, GTI-2179 "RESILIENT DIRECT PART MARKING ON CARBON STEELUSING LASER ENGRAVING AND COATING PROCESSES" on September 30, 2021.

Deliverables

The main project deliverables will be:

- Test sample logs of verifier reading
- Test samples for additional exposure beyond the initial test period of three years
- Final report with calculations projecting barcode life cycle estimates
- Recommendations for extending the life of the barcode protection processes based on the results of the testing

Benefits

In order to effectively track parts and implement maintenance plans, today's utility industry needs machine readable identification in the form of direct part marking that has an extended and known life cycle to atmospheric aging. OTD has generated accelerated corrosion testing data used to improve the chemistry in several test samples during the development phases of the project but has no real-world test data from weathering of test samples exposed to real weather conditions. This data is needed to prove the marking processes suitability for long term studies of trends in equipment through repeated scans of barcoded equipment both in service and in storage.

Technical Concept & Approach

Manufacturer 50-60 Test samples for testing

Purchase of materials and labor to manufacturer between 50 and 60 new test coupons for exposure in a salt fog chamber, atmospheric test sites.

Purchase verifiers and supply labor to perform verification measurements for three years

Purchase test equipment and labor to conduct verifier reads of accelerated corrosion samples and atmospheric test samples at test sites.

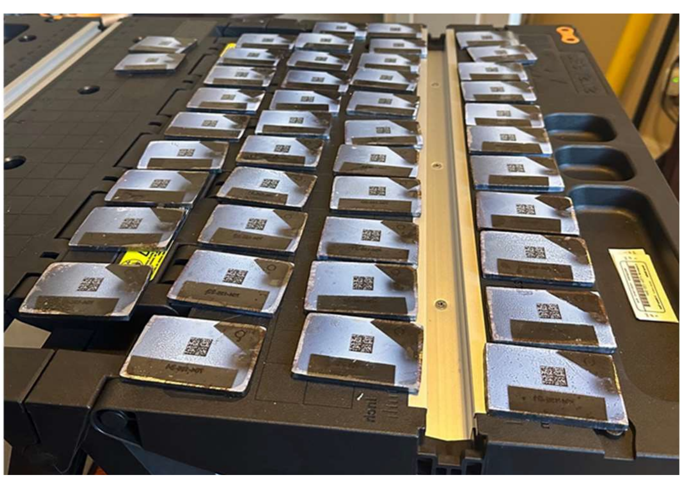
Correlation and prediction of barcode life, Project Reporting

Correlate accelerated corrosion verifier reads with atmospheric corrosion samples and project actual life cycle viability of naturally weathered test samples at both test sites.

Report analysis of testing. This program will be initiated for three years of testing and will be extended an additional three years if needed to project the total life cycle of each naturally weather sample set.

Results/Status

OTD ran a series of preliminary engraving trials to establish the total time required to engrave barcodes larger than the initial size barcode developed in the first two phases of this project. After discussions with the corrosion testing laboratory on the capacity sizes of the carrier fixtures to hold the test coupons in the test chambers, The team increased the total number of corrosion test coupons to seventy (70). Thirty-five (35) 1/2-inch and ¾-inch coupons were ordered in late July. The order for the corrosion test coupons was completed for pickup on September 28. The test results from the preliminary testing discovered that it takes less time to engrave a ½-inch or ¾-inch barcode than the smaller three eights (3/8) size. The laser cleaning processes are much quicker when engraving the larger barcodes, reducing the time to engrave by almost 50%.



Test Coupons

The team is researching and soliciting pricing on one or two barcode verifiers to start the corrosion program testing phase. Most verifiers are designed to verify barcodes printed on labels. For this project the verifier uses the verification equipment on direct part marked steel specimens where the steel corrosion test coupons may be difficult to mount in the barcode verifier. The team selected a verifier to purchase.

Trial verification tests were conducted in late December to develop scanning techniques of the same barcode to ensure the repeatability of subsequent scans. From the results of this work, it was determined that a fixture must be constructed on the table of the test stand to ensure the precision placement of the test coupon. Precision placement is needed to ensure from scan to scan, over the test period of weathering exposure, the position of the test coupon is repeatable to avoid introducing variability in the data from scanning different regions of the barcode due to alignment differences.

The team is focused on tasks to prepare for testing including establishing a test coupon database to store verification data and provide a means of analysis and verifying all the test coupons.

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OTD Operations Technology Development

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

Open-Path Laser Continuous Methane Monitor

- 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. This allows operators to become more proactive in monitoring and identifying leaks within their system. The system will use state-of-the-art methane sensing, wireless connectivity, and web-hosting technology.

Deliverables

Deliverables expected from this project include a use-case specification for an automated leak-detection system for temporary deployment, a 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, and functional prototypes deployed 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. This may allow for field personnel to perform other higher risk or other compliance activities. Information provided by the monitor can be used to target personnel activities where they are most required.

Technical Concept & Approach

Specific activities include:

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/Status

The team investigated several communications technologies and methane sensing technologies. These were evaluated in various combinations that could reasonably be deployed. The goal was to develop a set of reference designs that could be used for this purpose. The team consulted project sponsors to determine if there were specific applications for continuous methane monitoring that they would like addressed.

The communications methods that the team examined were LoRaWAN, LTE cellular, and Silver Springs Network AMI. Identifying the appropriate communication method are dependant on an operators unique system design and operations. The geographic dispersion of the methane sensors, the existence of wireless coverage, and any pre-existing AMI network all need to be factored into the communications choice.

Two methane sensor manufacturers were examined: Dynament and Nevada Nanotechnology. The devices have similar hardware interface characteristics but use different gas sensing technologies internally. The Dynament sensor is methane specific; The Nevada

Scientific Aviation Soofie Point Sensor

Nano device can detect multiple gases. Both devices showed a methane sensitivity threshold of about 1,000 ppm. Nevada Nano recently released a methane sensor with a 50ppm threshold; this model was not available during the active phase of the project.

Differentiating between different gases such as hydrogen and methane are of increase interest to operators who are looking to decarbonize their systems. The Nevada Nano MPS Sensor can differentiate gas species by molecular weight. The sensor does not provide detailed constituents but differentiates between hydrogen, methane, and heavier hydrocarbons by molecular weight. The heavier hydrocarbon category would cover newer refrigerants like R290.

During the course of this work, there was a great deal of commercial activity in Residential Methane Detectors (RMD) and continuous unattended methane monitoring. These commercial developments align with the objective of this project in identifying solutions that aide in continuous monitoring.

The current project is being closed and a Final Report has been provided to OTD members.

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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 involved 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 BPMN documentation, recommendations, implementation at one utility, a webinar presenting project results and a final report.

Benefits

Increased safety via broader application of pipeline safety management concepts into more programs and reduce costs associated with risks and unintended consequences related to business changes.

"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/Status

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.

Researchers met with sponsors to discuss successes and challenges in implementing pipeline safety management programs. These included discussing incident investigation, evaluation, and lessons learned. The team also created training videos to explain the concept of BPMN, the notation, and prepared an Educate & Enable PSMS market strategy with stakeholders to solicit feedback, garner support, and increase clarity.

The team delivered a final Recommendations for Repeatability & Practice whitepaper to close out the project.

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Project No. 8.20.i

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.

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.

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).

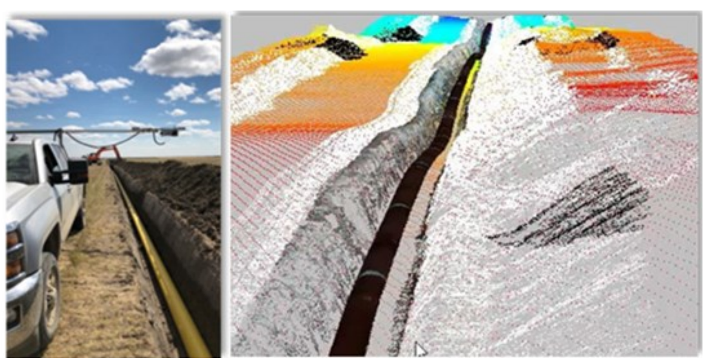
Deliverables

- 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.

This automation will ensure that the device is connected to the appropriate high-accuracy GNSS source and eliminate the need for additional tools.



Lux Modus truck-mounted scanning system

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 for this project 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. 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.

Leica scan with LiDAR point cloud and imagery combined

Results/Status

In the fall of 2019, the team began researching companies that could provide a digital twin scan using LiDAR (light detection and ranging) and high-resolution imagery. The goal was to find a solution that employed an easy-to-use data collection platform and provided adequate results that could be used for data feature extraction to GIS. The team reviewed products from three separate companies. Each platform offered something a little different in terms of how the data was collected and the results of the data output.

Images from these tests were fed into an online image and text recognition platform. The goal of this analysis was to examine what gas assets from the scan could be identified for proper placement and attribution within a GIS system. This would go as far as attempting to locate, identify, and decode a barcode from the scan itself. Some products produced higher quality images than others.

During these evaluations, the team also investigated creating a product that could be used during the scan to identify and decode a barcode using a small micro-processing board paired with a camera lens. The lab results were fair, but more work will be required to determine if this is a viable path for automating the tracking and traceability process.

This project is complete and a final report has been shared with OTD members.

More information can be found on the second and third phase of this project in a separate summary.

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Project No. 8.20.i.2

Automations for Tracking and Traceability

Researchers are working to automate data collection techniques used for tracking and traceability which will ease the collection of traceability data and produce a digital twin which can be referenced or compared to future scans.

Project Description

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 (LIDAR and High- Resolution Photography), field crew workers can remain safe outside of the trench and allow the scanner to capture the natural gas assets. 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

The main project deliverables will be: field test 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

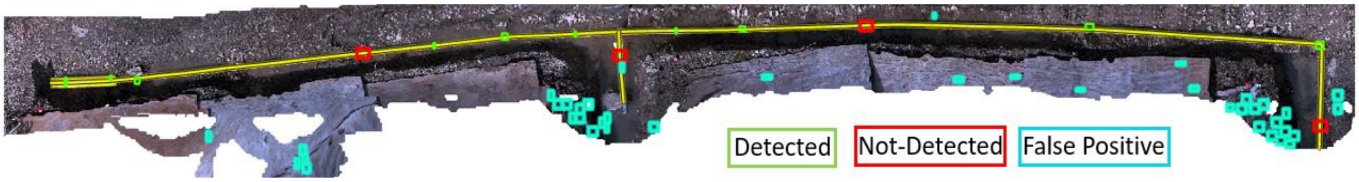
Data collection using automated techniques not only keeps people safe, but it will also expedite the recording process of the gas system. Standard data collection methods require the user to enter the trench with a high accuracy GNSS device to collect each asset as they navigate around the pipe. The 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. In addition to scanning and converting data into a GIS, these scans will also serve the purpose of providing a historical digital twin. Users who have questions will be able to recall the scan and visualize the assets that were installed before backfilling. This automation will ensure the device is connected to the appropriate high-accuracy GNSS source and eliminate the need for tedious additional tools such as barcode scanners, poles and tablets currently used for traceability data collection.

Technical Concept & Approach

Technology Implementation

The project team will work with LuxModus to design the workflow of scanning, identifying, and mapping of natural gas distribution sized assets. This will also involve developing the necessary data collection processes, cloud environments, databases, and software in accordance with this design.

Electronic Pushcart with Scanner Performing a Scan at a Sponsor's Project Site



Butt Fusions and Electro Fusion Objects Detected and Extracted Including False Positives

Technology Field Testing

A testing matrix for evaluating data collection quality will be developed. This will include collecting high-resolution LIDAR and photography via LuxModus scanners and a comparing data set using standard GNSS receivers.

Results/Status

The team focused its efforts on building a cart to hold the Lux Modus scanner and thus reducing the footprint of utilizing a truck or an ATV in a more confined setting often found in distribution sized gas installations. The team borrowed a LiDAR and high-resolution imagery scanner from Lux Modus to perform multiple scans. In parallel, the team acquired multiple images of butt fusion and electro-fusion gas assets and tagged them respectively using software dedicated to building object detection frameworks. As field scans were completed and a detection library was constructed from the tagged images, the team then brought the extracted features produced by Lux Modus into a mapping environment alongside the detected objects from GTI's trained model.

The combined detection results were successful. Modifications have been documented for future research including utilizing something other than the electronic pushcart for scanning and removing the potential of false positives in GTI Energy's object detection model. The lessons learned on this project will prove invaluable as they help guide GTI Energy's focus for the next phase of the Automations for Tracking and Traceability project.

This project is complete and a final report has been shared with OTD members.

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Automations for Tracking and Traceability

Researchers will continue research on improving the data collection techniques used for tracking and traceability and migrating that data into a GIS system with automated procedures with a focus on alternative data collection methods such as drones and cell phones.

Project Description

The objective of this project will be to continue research on improving the data collection techniques used for tracking and traceability and migrating that data into a GIS system with automated procedures. The focus of this phase will be alternative data collection methods (i.e., drones, cell phones, tablets) while continuing to collect data for training an object detection model. As this model grows, it will be tested for its ability to identify and extract natural gas components from field-collected imagery and move the extractions into GIS. The benefits of this automated process will provide the users with a digital twin record of the open trench and allow data to be collected safely and efficiently with very little human intervention and reduced chance of error.

Deliverables

The main project deliverables will be: field test results; documentation on the performance of the selected field collection devices and detection results, documentation of data workflow including project set-up, data collection, data processing and results; and a final report

Benefits

The ability to collect data in an automated fashion will reduce costs, increase data quality through eliminating data entry issues, and eliminate the need to put field crews in unsafe conditions in order to complete data collection tasks.

Using a one-pass data collection technique can gather data within a few minutes. Results will be derived from the computer's ability to identify

Electronic Pushcart with LuxModus Scanner

Digital image of a scanned pipe

natural gas components and convert them to usable GIS features. Moreover, as research continues, detecting and decoding barcodes from the imagery can happen in parallel as a value add to the tracking and traceability process. The stored data becomes more valuable with the user's ability to visualize these assets as they were installed prior to backfill.

Technical Concept & Approach

Specific activities include:

Hardware and Software Review

The project team will research costs and functionality of newer data collection devices and their ability to collect high resolution imagery and LiDAR (i.e., new iPhone or tablet, drones). The project team will also purchase a subset of new devices based on costs and research, and document the benefits and considerations for operators to review prior to selecting these devices.

Object Detection Model Training

The project team will receive images from participating sponsors and begin to label images for object detection. Existing models will be re-trained based on newly labeled images and test accuracy of prediction. A document of image collections for each natural gas component being trained and tested will be created.

Technology Implementation & Testing

The project team will collect data via selected devices and store in a centralized location. Images will be run through object detection model in a desktop environment and review detected assets. Images will be reviewed for positional accuracy by comparing detection location to the existing location determined with a high accuracy GNSS receiver. The model will also be migrated to a cloud environment and test functionality of passing collected images to this environment for detection.

Results/Status

The team worked with Verizon to purchase an iPhone 14 for LiDAR-based scanning options with the Pix4D RTK attachment. The team installed and reviewed the Pix4D desktop applications needed for iPhone imagery and LiDAR uploads and data processing and performed a few test scans of above ground pipe.

Project sponsors provided images of natural gas components and the team completed the data preparation and cleaning of the input data set. The team has completed data labeling for about half of the training data set with the remaining underway.

Once the training dataset is ready, the team will utilize the labeled data set for model training using ESRI’s Deep Learning libraries and test the model’s performance using a test data set.

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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.

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.

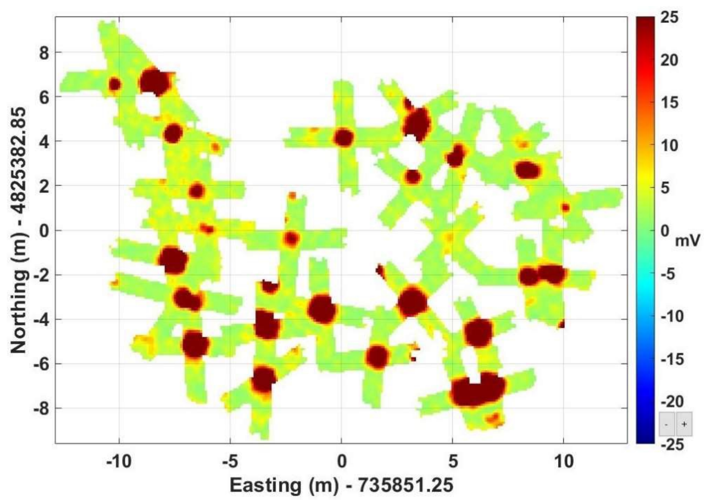
Plastic pipe is particularly challenging to locate. According to the Common Ground Alliance 2015 DIRT report, improperly located or undetected subsurface utilities resulted in 1,906 injuries, 421 fatalities, and $1.7 billion in damages over 20 years. Most locating technology cannot accurately detect 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



Detection map created from the cued APEX survey. Short transects were acquired over the locations of detected anomalies to increase the SNR of the data used for subsequent analysis.

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/Status

In this project researchers evaluated using a new electromagnetic induction sensor, the APEX, developed by White River Technologies (WRT), to detect, locate, and characterize service tees. The APEX was developed for the Department of Defense to detect and classify buried unexploded ordnance; however, it can be used for any subsurface locating applications that involve buried metal. WRT tested the APEX sensitivity to various service tees to establish the maximum detection depth for these items. WRT then performed a field demonstration with service tees buried at depths within the established operating envelope. Results indicate that the system currently can detect most tees to depths of about 2 to 3 feet, depending on the size and amount of metal in the tee. Within this depth interval, the system can accurately locate the tees to within about 10 cm accuracy.

Through this research effort, the team implemented a library matching method which was used to accurately characterize and locate service tees buried at depths ranging from 2 feet to 3 feet. The library match method demonstrated that it was possible to locate and identify service tees in a cluttered area with a significant reduction in false alarms.. Additionally, analysis of the 3D electromagnetic induction data provided accurate location estimates of all buried service tees.

Tee emplacement process.

The current operating specifications for the APEX sensor enable accurate detection and classification of service tees between 2 – 3 feet of burial depth, depending on the size of the tee. WRT estimates that, in practice, the largest tees (2-inch outlet size) can be detected, located, and characterized effectively to depths of about 3 feet. Extending this depth range would require modifications to the sensor operating parameters. Potential modifications to increase depth include increasing the transmitter power and increasing the receiver sensitivity.

This project is complete and a final report has been issued to OTD members.

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Project No. 8.20.l

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.

This project focuses on advanced 3D electromagnetic (EM) methods. These technologies offer enhancements in pipe detection and localization. Specifically, the full 3D response of the target is captured via an array of triaxial receivers, providing an improvement in resolution. This project will conduct testing on the White River Technologies' (WRT) 3D electromagnetic induction (EMI) solution called APEX and Reduct's in-pipe mapping probe.

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 a stakeholder requirements document, a baseline performance document, a system optimization document, and a system performance document.

Benefits

The key benefits of this solution include damage prevention and which helps maintain pipeline safety, safety of the public, and reliability. This is achieved 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 value and knowledge of their infrastructure to gas operators.

Technical Concept & Approach

The project team will set a baseline estimate of the capabilities and performance of existing technology as it performs before optimization. This will be followed by conducting field tests at sites volunteered by California utilities to demonstrate the improved technology under a variety of field conditions.

Upon completion of the field tests, 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, and determine the steps needed to lead to the manufacturing of technologies developed in this project or to the commercialization of the project's results.

APEX operation in the chariot mode (top left) and hand-carry mode (middle) using the hand-carry attachment. The lightweight design (right) offers additional capabilities to survey in challenging environments.

Results/Status

For this project the team created a baseline estimate of the capabilities and performance of various mainstream or commercial locating technologies. These baseline data were used for comparison and validation of the APEX and in-pipe locating technologies versus commercial electromagnetic (EM) sensors. The team used GTI Energy's existing facilities to execute a field calibration survey to document the 3D positional accuracy of the mainstream EM locators, with a particular emphasis on vertical positional accuracy. The results of this survey were used to establish the minimum performance requirement to demonstrate the 15% accuracy improvement. To ensure that the baseline being established had a highly accurate dataset for its horizontal and vertical spatial positioning, GTI Energy designed and installed a brand-new pipe system in its pipe farm. High-accuracy survey of the open trench was performed prior to backfill to establish the true 3D positions of the installed pipe system. The commercial EM locators, APEX system and in-pipe technology were all used to perform utility locates at the pipe farm and the positional error estimates were generated for comparison.

Based on field data that was obtained, WRT was able to implement both hardware and software upgrades to improve the positional accuracy of the APEX system. The APEX system, the in-pipe technology and one EM locator were used for pilot demonstrations at multiple utility sites. Potholing was done at two sites to generate ground truth data and develop error estimates of the APEX and EM locator surveys.

The key results included comparison of the vertical error estimates between the commercial EM locators, and the APEX, and in-pipe technologies using the survey data from the baseline pipe system at GTI Energy’s pipe farm. In addition, horizontal and vertical error estimates of the APEX and one commercial EM tool were compared from the pilot demonstrations at two utility sites.

. Based on the survey results at two pilot demonstration sites, compared to the commercial EM tool, the APEX system showed 30-73% reduction in horizontal errors and 80-97% reduction in vertical errors.

The team performed pilot field demonstrations and analyzed the results of the field testing at multiple California utility service territories to demonstrate improved underground pipe-locating technologies across various field terrains and conditions.

This project has been completed and a final report has been released to OTD members.

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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

Knowing where buried infrastructure is located can aid in mitigating the risk of excavation damage and preventing such damages from occurring. Additionally, there are potential environmental impacts to consider as pipeline damage may result in natural gas leaks,

increasing the likelihood of greenhouse gas emissions.

A system that collects, stores, and displays more precise locations of buried natural gas infrastructure and assets would benefit gas utility operators and the general public.

The solution developed in this project seeks to improve the safety and integrity of underground natural gas infrastructure by increasing the accuracy and availability of horizontal and vertical pipeline location information. More accurate locate results will aide in minimizing excavation damage.

Deliverables

The deliverables for this project include the business requirements, hardware/software interface requirements, software and system documentation, the source-code repository, testing documentation, and pilot analysis.

Benefits

Visualization software can help prevent future excavation incidents caused by inaccurate locate markings or insufficient locate practices.

Business process models are being created to outline potential process improvements an organization may take in order to improve the geospatial accuracy of existing Geographic Information System (GIS) data in both the horizontal and vertical dimensions.

Technical Concept & Approach

Determine Data Integration Approach

Determine how to integrate the required data sources and transmit real-time information from the utility-locate tool and GNSS (Global Navigation Satellite System).

System Requirements and Design

Develop the requirements for the software system and utilize this documentation for auditing and testing purposes.

Develop Cloud- and Field-Based Platform Components

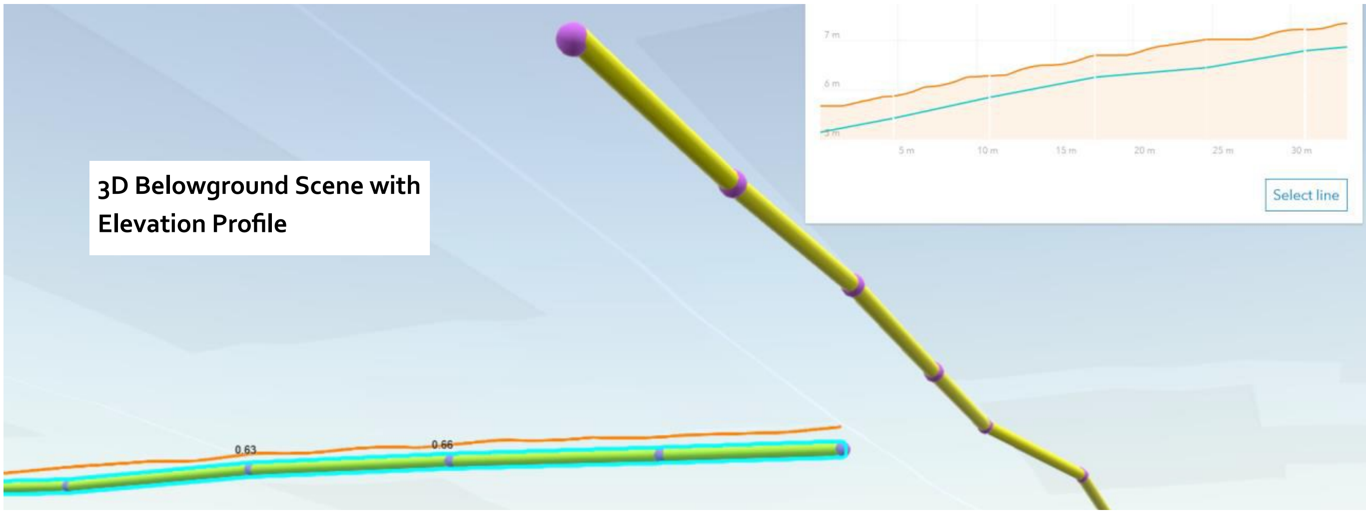
Develop cloud-based software that integrates the required data sources. The platform must provide both field and office users with visualizations of the infrastructure location and metadata.

Perform System Testing

Conduct system testing on sample below ground pipe to validate system performance and functionality.

Pilot Demonstration and Analysis

Conduct a field test at sites volunteered by California utilities to demonstrate the improved technology under a variety of field conditions.



Production Readiness Plan

Determine possible approaches to commercialization.

Results/Status

The team successfully designed, developed, and tested a field-based application to collect, store, and visualize underground gas infrastructure location information. The Windows application allows utility locate personnel to gather and store field-collected utility locates (i.e., gas, water, sewer, etc.) in a digital format. Newly captured locate information is displayed alongside existing data and available to field and office-based staff in real-time. Users may toggle between 2D and 3D map views to visualize utilities from either an above or below ground perspective. Additionally, users may perform queries to retrieve valuable site information and enter unique site conditions.

The high-accuracy (defined as geolocations within a foot of those established by proven methods) data collection system performs as designed. The level of precision and accuracy of the collected data depends on a wide range of factors, including the hardware used, situational conditions and circumstances, and operator technique.

The system operates via a straightforward workflow that links the locate device and the field tablet via Bluetooth, streams locate information from the device to the tablet, and transmits the location and additional manually entered information over a cellular network to a cloud database.

The team executed system testing at GTI Energy's pipe farm in Des Plaines, Illinois. The software and utility devices performed as expected and validated the application's readiness for field pilot demonstrations.

A six-month pilot demonstration was conducted with two operators. By the pilot's completion, more than two miles of underground gas lines were located via a combination of electromagnetic and ground penetrating radar devices encompassing various soil types and pipe materials and sizes.

The team identified two models for turning the prototype software application into a commercial product. A report summarizing the findings was provided to OTD in March of 2024.

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Mobile Leak-Classification Application

A mobile application has been developed which 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 is a federal requirement for a gas pipeline operator, including the training and qualifying of an employee to determine the severity and gravity of a leak. Tools like check charts are required to properly aid in classification, recording, and assigning a priority for leak repair. The application being developed in this project will complement decision making by the field crew and add consistency in the operation.

There are situations where classifying a leak can be simple for an employee. However, even with training and support from guidance manuals, there is a desire from operators to approach and evaluate leak events with the consistency across their organization. One method, such as using an electronic tool, will help reduce 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 the tool, which calculates a leak classification, and recommends a course of action in real time.

Deliverables

This project provides a smart form for purposes of leak classification activities on a natural gas pipelines. The deliverables for this project include a leak-classification guidance table/ decision tree matrix, a smart form checklist for leak classification requirements, a leak classification electronic smart form in survey123 format, a demonstration on how to download and use the developed smart form, and support documentation. The application outlines the industry accepted GPTC (Gas Piping Technology Committee) for Gas Transmission and Distribution Piping Systems) guidance, when performing an outside gas leak investigation and classification covered task.

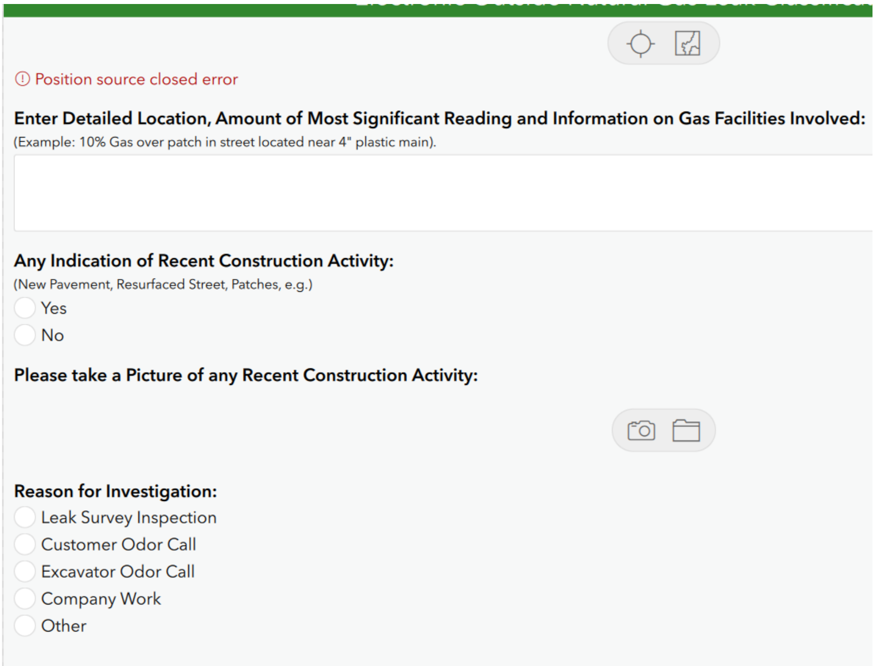
Benefits

An electronic tool will help reduce the risk of inconsistencies by utilizing the preconfigured smart logic functionality built into the application. Having access to a well-structured and organized set of leak-classification guidelines can improve the consistency by which leaks are evaluated and assessed in the field. In the field, leak investigators and survey personnel face difficult scenarios while classifying leaks.

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.



Sample questions on the Smart Form

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/Status

Using the GPTC guide as a resource, the team developed two documents capturing various requirements related to Leak Investigation and Classification activities. These two documents were used to develop the questions within the smart form and served as the project deliverables of the Leak Classification Guidance Table/Decision-tree Matrix.

The draft version of the smart form was made available for project sponsors to test out after the meetings to receive further comments and feedback for enhancements or improvements. The comments and feedback from the project sponsors were recorded and the smart form was updated accordingly.

The finalized version of the smart form can be accessed via a web browser or through the Survey123 mobile application. The team demonstrated the final version of the smart form during a call with project sponsors, detailing all the capabilities and functionality built within the form.

This project is complete and a final report has been released to OTD members.

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High Accuracy Locator Technology Evaluation

Researchers will assess new technologies in underground utility equipment locating. These technologies can increase the accuracy of locating and identifying underground assets which will improve the safety of gas operations and enhance emergency response capabilities.

Project Description

This project is aimed at assessing new technologies in underground utility equipment locating. These technologies integrate data from electromagnetic (EM) utility locators and high-accuracy Global Navigation Satellite System (GNSS) devices.

The evaluation is focused on the spatial accuracy of the locates, how workflows may be affected by the introduction of these technologies, and ease of use of the evaluated technologies. The team will set up a standard testing environment to conduct comparative analyses of the technologies.

In Phase 1 of this project these technologies were tested in a controlled environment. The testing of these devices occurred at three separate locations with slightly varied backfill materials and some differentiation in the method for establishing a traceable underground signal (i.e., tracer wire and locating tape). For the most part, many of these solutions performed well when locating the underground pipe in a testing environment.

Various backfill materials

In this phase, the team will apply these solutions in more of a real-world setting with utility-congested streets, varied distances from an RTK base station, and the ability to retain connection with that base station would be the next step for utility companies interested in understanding the capabilities and limitations of these solutions.

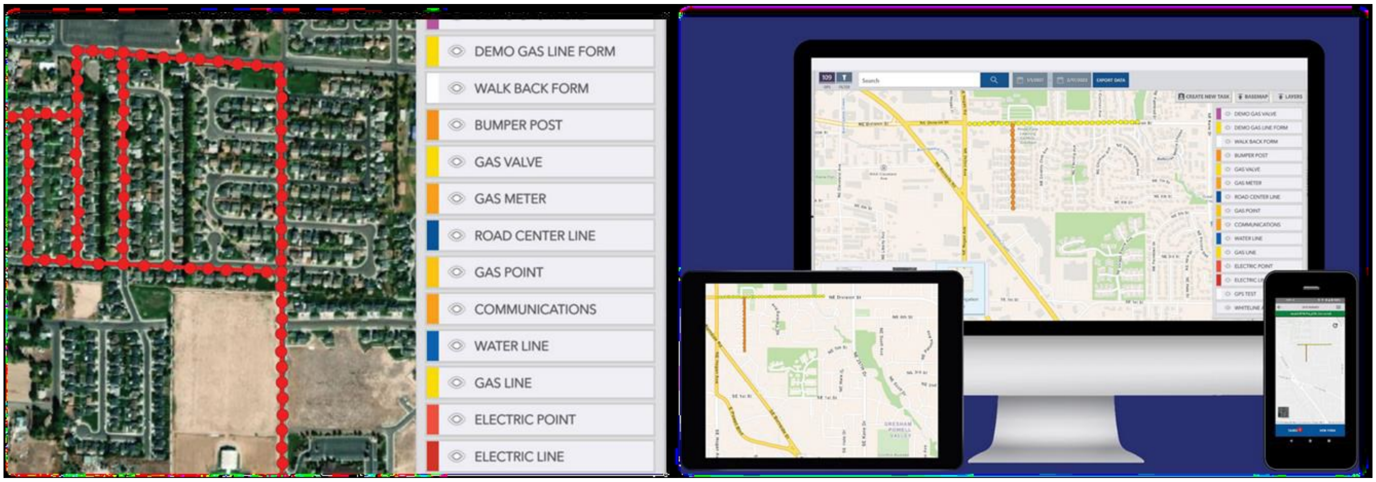
Deliverables

- The deliverables for this project will include the following work products:
- A quantitative comparison of each selected solution, including horizontal and vertical position accuracies, as possible (depending on availability of reference data for comparison) and subjective assessments of ease of use, etc.
- Final report and project closeout meeting

Benefits

Increasing the accuracy of locates and identifying underground assets and optimizing locating workflows can increase operational efficiencies, improve safety of gas operations, and enhance emergency response capabilities.

'Pipe farm' with open trench pipe installation



Pipeline Survey Application by LaunchPoint

By integrating high-accuracy GNSS receivers with locators, it is possible to improve horizontal (X, Y) data and combine it with depth/vertical (Z) data, unlocking additional capabilities within geographic information systems.

Technical Concept & Approach

Identify Test Sites and Subject Technologies

Engage project sponsors to identify the equipment and software they want to test. Sponsors will determine where and when that testing will be conducted. Prepare for testing by acquiring and becoming familiar with the hardware and software that will be tested.

Field Testing and Analysis

Partner with sponsors to test the selected technologies at sponsor locations. Compare locating technology for accuracy in locating underground utility infrastructure and for usability.


EM Utility Locators evaluated in 8.21.b

Results/Status

OTD is continuing to gain proficiency in the use of the equipment and software that will be tested. Decisions on testing sites and dates will be made in March or April of 2024. Existing field test-site data will be analyzed so that it can be compared with the data generated during field testing.

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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 typically propelled by gas pressure or self-propelled via a tether cord that provides control and power. These tools collect several types of data including visual, audio, position, pressure, eddy current, magnetic flux leakage, etc., which helps operators identify corrosion and map the infrastructure.

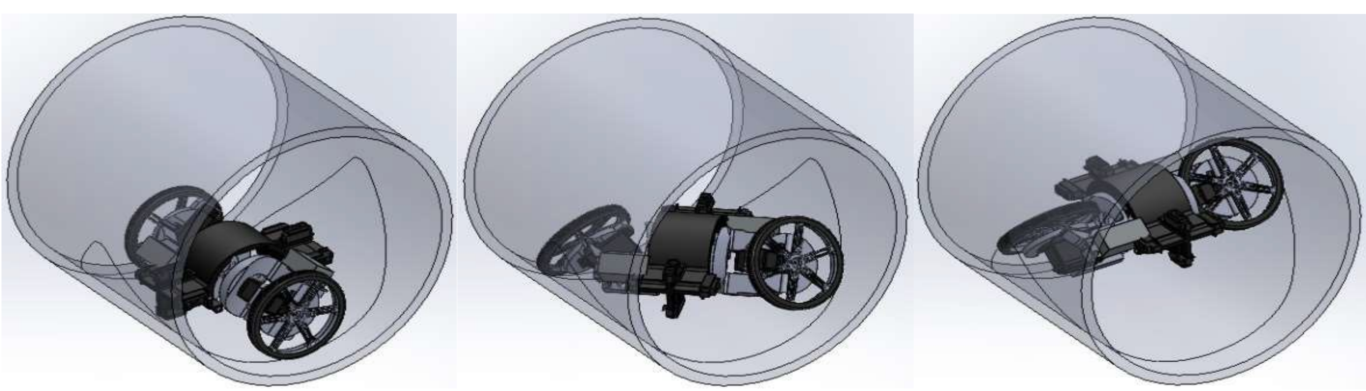
Historically, ILI devices can only collect this data in locations that do not contain tees, sharp bends, or where that are of a diameter smaller than existing ILI devices. Many self-propelled ILI devices are also limited by the length of their tether.

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".

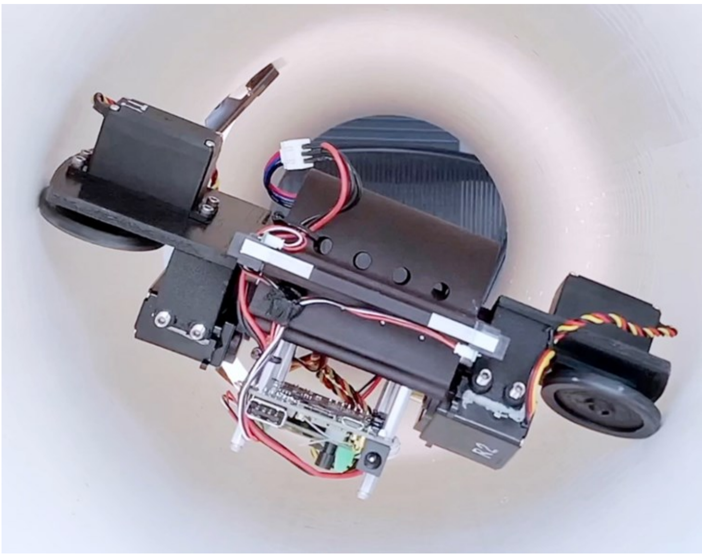
This project is to build upon past progress on the Pipe Rider platform by adding an additional level of control. Pitch control will give this pipe crawler two critical performance features: 1)the ability to stay aligned with a pipe's center axis regardless of the angle of the pipe underground and 2) the ability to turn a corner when an elbow or tee is encountered. 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.

Deliverables

The main project deliverables will be project communications and presentation materials, a final report, and a sponsor demonstration.



(Left) CAD Model of PipeRider_YRDR in Deployed Position, (Center) CAD Model of PipeRider_YRDR Halfway up Pipe Wall, (Right) CAD Model of PipeRider_YRDR at Pipe Center



Pipe Rider inside a pipe

Benefits

This new device can gather additional pipeline data for pipelines that were previously not piggable. Additionally, because this tool can travel longer distances, there is more flexibility in where the tool will be launched from, and more ideal locations can be selected. Fewer insertions will save operational teams time and reduce customer disruption due to excavations.

Technical Concept & Approach

The project team will work to develop equations of motion for the force needed to rotate Pipe Rider for negotiating pipe elbows or tees and use solid modeling to create space inside a main body for new components. Build a test stand to prove out motor sizing and torque output, and incorporate a new reaction motor into a new functional prototype. The project team will test pitch control for turning capability in a laboratory environment.

Results

The team was able to make substantial improvements to the PipeRider and validate the capabilities necessary to become a fully autonomous in-line inspection robot. In testing the in-line inspection tool was able to spin 90 degrees, and climb the pipe wall as it transitioned from its retracted state to its deployed state.

Not all tested functionality worked without issue. The pitch control and deploy-retract worked in their test environments, but not as expected. The team was unable to find smaller motors in order to test the full deploy-retract movement of the PipeRider. The motors used were too large to allow the motion necessary for the deploy-retract movement. Further work is required before the PipeRider can be tested in a pressurized pipe.

Status

This project is complete and a final report has been shared with OTD members. At the end of this project OTD was awarded funding from the Army Corps. of Engineers Construction Engineering Research Laboratory (“CERL”) to collaborate with Professor Tom Bewley’s team at UCSD and Kurt Talke’s team at NIWC PAC. In this CERL project, the NIWC PAC team will utilize their knowledge to further develop the PipeRider.

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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

The U.S. Department of Transportation's Pipeline and Hazardous Materials Safety Administration (PHMSA) defines requirements to establish potential impact areas. Potential impact circles are used to identify high consequence or moderate consequence areas (HCAs or MCAs), and operators are required to perform additional assessments to ensure pipeline and public safety.

In 2019, PHMSA published an update to require new regulations for integrity assessments conducted outside of High-Consequence Areas (HCAs). The regulations use the same data sources to establish PIC/PIR and HCAs.

The current methods of conducting population analyses and building potential impact circles uses U.S. census data. The objective of this project is to improve the accuracy of classifying HCAs and MCAs through modern data analysis and data sources.

This helps operators better understand how to manage pipeline risk and ensure their pipeline systems continue to operate safely.

Deliverables

The deliverables for this project 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.

Benefits

Developing the capabilities to leverage more accurate and modern data sources can help reduce labor hours categorizing new development, 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

Specific tasks for this project include:

Research Cellphone 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.

Building Outlines Detected from Esri's Deep Learning Model and NAIP Imagery vs. NYSEG Building Footprints

Results

Building detection using satellite data

The team utilized ESRI's deep learning model for building detection. For the first two tests, the team utilized relatively low-resolution satellite-based sample images. The team found that the results on the number of buildings detected can vary based on the image resolution and the type of imagery used to train the model. The model identified approximately 27% and 21% of buildings in these tests.

The team then used higher resolution data created by an airplane flyover. In this case the model identified approximately 96% of the structures that were present. In the last test, the team applied the model to higher-quality satellite imagery sample for a subset of the service territory where the testing was being performed. The model identified approximately 55% of the buildings.

The team was also interested in evaluating differences in building footprints to detect changes. The team used ESRI's Symmetrical Difference Tool to compare the original building footprints provided by the operator, against those generated from the plane-acquired imagery. The accuracy of this approach is limited by the fact that the two datasets were generated in different ways, but it provides a proof of concept on how the square footage differentials could be determined.

Mobile data analysis

The project sponsor supplied building structures and outdoor area shapefiles near the natural gas pipelines, which would be used for data comparison and analysis purposes. A match between cell phone data queries and the existing structures within one operator's service territory provided proof that the cell phone data could be used for HCA structure and outdoor area analysis to some extent. However, the results did not return as many matches as hoped and, thus, left the cell phone data as more of a supplemental dataset to the traditional field data collection methods. Using cuebiq data alongside another anonymous cell phone provider would potentially create a hybrid approach and may improve these results.

Status

A final report has been submitted to OTD members. The OTD team has proposed a second phase of this project which will focus on finding better-resolution satellite imagery and using one or more cell phone mobility data providers. The goal is to build upon the current strategy and improve the accuracy of identifying changes that may impact HCA and MCA classification.

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Project No. 8.21.g

GNSS Testing in an Urban Environment

This project involves an investigation into current technology enhancements that can help field data collectors in 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, but the signals are weak and can be blocked by blocked or reflected by buildings. GNSS receivers used for data collection also need good sky geometry to compute an accurate position. 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

Finding ways to improve the accuracy and performance of GNSS in the urban environment will benefit utility operations, increase efficiency, and improve the reliability of their digital assets.

Technical Concept & Approach

Tasks for this project include:

Project Scoping

Identify the potential technologies and determine the most promising technology to move forward with testing, research availability, feasibility, and cost. The task will include purchasing equipment and materials needed for testing.

Select and Set Up a Testing Site

Identify one or more testing locations representing the urban canyon environment used for testing. Set up control features that will be used to compare the testing results.

Field Testing and Data Analysis

Field test of all the subject technologies and analyze the results.

Results/Status

The team researched several solutions that showed promise for geolocating in urban canyons with less expense, shorter time and lesser expertise requirements.

The researched solutions included improved GPS positioning in Android via 3D mapping aided corrections, Verizon's Hyper Precise Location, E-nails from the Research & Innovation Center for Energy of GRTGaz, Imajbox by imajing, and Inertial navigation systems (INS).

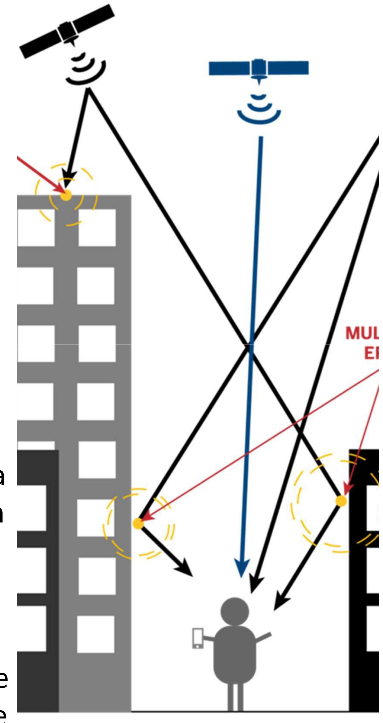
After evaluating the performance potential and feasibility of the above technologies, the team determined that (INS) were the best candidate technology for the urban canyon problem that worked within this project's constraints.

Two INS devices were acquired for several weeks of evaluation. These devices were initially tested at GTI Energy's campus in open-sky locations where the GNSS signal was good and where it was not. The testing circumstances were intended to roughly simulate an urban canyon, in which some locations have better GNSS signal than others. The team also gained familiarity with the equipment from this activity, and it provided preparation for the next phase of testing in downtown Chicago in true urban canyons.

The two INS devices were tested in part by measuring how well they deduced the positions of control points around the GTI Energy campus, whose geolocations have been determined with high accuracy using traditional surveying techniques. The positions of these points were also measured during the project using an Eos Arrow Gold (a standard GNSS receiver) for comparison against the INS devices. The same procedure was also used in downtown Chicago, with the addition of control points in urban canyon areas created using laser range finder technology.

The team noted some challenges in using each device. The first device was difficult for surveying on foot. The team 3D printed a holder which allowed the second device to be attached to a survey pole in order to hold the second device securely while walking.

The backpack of the second device was heavy, so doing several hours of surveying with it could be taxing. Having the antenna in the backpack introduces some imprecision to the surveying process, as positioning the antenna over the point of interest involves some uncertainty due to the antenna's position relative to the backpack wearer.



Both devices have a learning curve and more steps to start the surveying process. The devices do not communicate with mobile GIS apps like Field Maps, making their use less familiar and more involved than a traditional GNSS receiver. The software required during the survey process requires a Windows device for both devices.

The first device was not tested in a true urban environment because the team could not complete the spatial calibration specified as a requirement for good results from the device. The software that monitors the calibration process never provided the final indication of the successful calibration.

The second device was able to capture more accurate location information in urban canyon environments than the GNSS receiver. Its performance in open sky was less precise and accurate than the Eos Arrow Gold.

This project is complete and a final report has been issued to OTD members.

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Project No. 8.21.h

Tracking Software Development for Pipeline Safety Management Systems

Researchers created a prototype software package that organizes and tracks pipeline safety management progress in order to assist gas operators in mitigating risks, increasing compliance, and promoting safety at their organizations.

Project Description

The objective of this project is to create a software package that organizes and tracks pipeline safety management progress, as defined by the American Petroleum Institute's Recommended Practice 1173 (API RP 1173), and continuously reports a score to mangers that is based on the Pipeline SMS Evaluation Tool.

A software that meets this objective reduces the inefficiencies of using multiple and uncoordinated systems to track, manage, and report implementation progress of RP 1173's various safety elements. The software system aims to promote transparency and improve coordinated efforts across multiple departments and stakeholders. Adopting a phased approach, the team plans to design and build a functional prototype that will validate sponsor requirements and the feasibility for a full product.

Deliverables

This project will deliver requirements and design documentation.

Benefits

The software produced by this project will help gas operators mitigate risks, increase compliance, and promote safety at their organizations by leveraging a unified software platform to track and manage pipeline SMS efforts. Instead of having to manage the rollout of these efforts through a combination of spreadsheets and disjointed reporting systems, a unified software will significantly reduce these complexities and give mangers visibility into how these initiatives are progressing across their organization.

By incorporating Pipeline SMS' Evaluation Tool into the software, operators will be able to measure the progress and adequacy of their systems related to pipeline safety management through Key Performance Indicators (KPIs). As an operator makes changes to its system, or data is acquired, a continuous reporting system will incorporate new information and provide the KPIs to users through convenient and up-to-date dashboard reports. Providing a quantifiable measurement of progress and the effectiveness of an organization's safety management is an added benefit of the software that will deliver for gas companies. Through the process of continuous improvement, the proposed solution provides value to any operator regardless of how mature their respective pipeline safety program is.

Technical Concept & Approach

Tasks for this project include:

Requirements Gathering and Technology Assessment

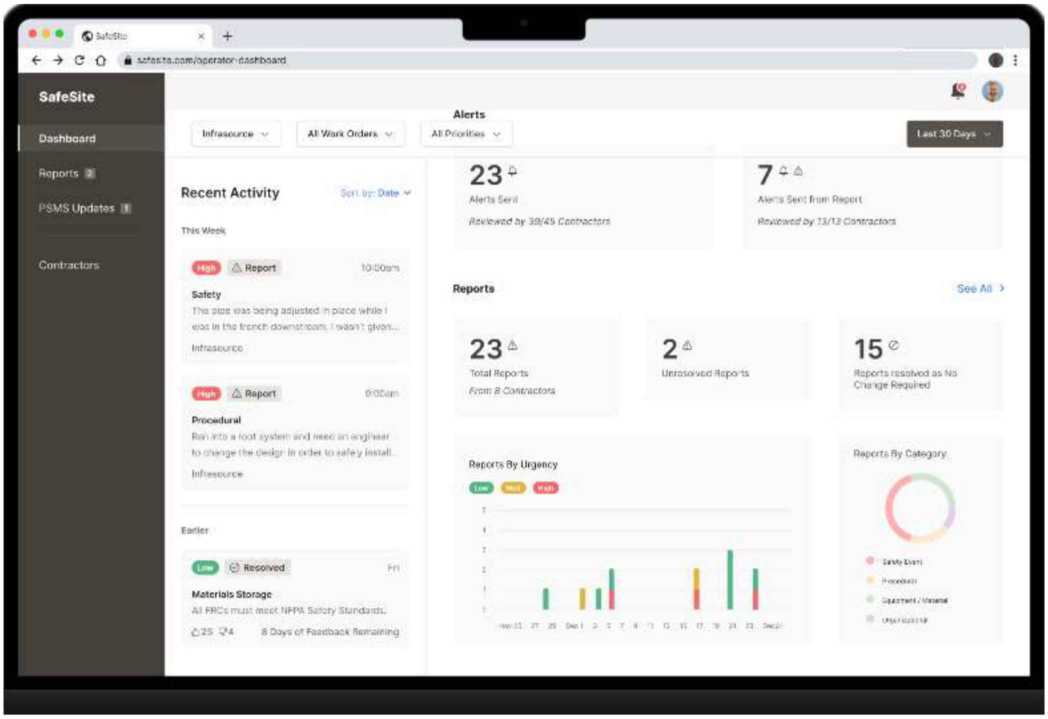
Develop requirements for the software system. Solicit sponsor input to assist in formulating the appropriate set of requirements and ensure the system will adequately address the needs of its intended users.

Software Design and Development

Create an initial set of design documents which reflect the software requirements. Construct the software system to meet the documented design.

Software Testing and Re-Work

Develop test cases, performing rigorous testing of the software, and make changes where issues are identified or where components do not meet the design criteria.



Results/Status

Through an information gathering process, the team developed eleven requirements and future system considerations begin to encompass a baseline by which a more comprehensive Pipeline SMS evaluation system may be developed. Business and system requirements for the prototype can be related to management of change controls, recordkeeping & documentation, pipeline SMS communications, competence & training documentation, risk management & reporting.

Using industry data, the team focused its efforts on first targeting operator and their contractor communications related to primarily operational controls (API RP 1173, Section 8) and documentation and record keeping (API RP 1173, Section 14). All Pipeline SMS elements are connected to an overall Pipeline SMS, so it is assumed that other elements, such as risk management (API RP 1173, Section 7), will receive value from these efforts.

The properties of the dashboard were designed for operators to easily understand, measure, and track KPIs within an element, and customize certain features as needed based on their desired performance goals. These measures are likely to alert to the need for, or influence, other activities within a holistic pipeline SMS evaluation tool.

There are four user types represented within this prototype: operator management (administrator), operator construction manager, contracting manager, and field contractor. The names for user types attempt to represent the wide spectrum of diverse roles and job titles currently existing within the industry.

The prototype workflow incorporates four user types, commonly identified Pipeline SMS roles and responsibilities of each, and three operational scenarios that were identified by OTD members. The results of the project were summarized in a final report and issued to OTD members in May 2023.

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Project No. 8.22.c

Implementing API 5L RP 5MT, "Pipeline Inspection Documents for Material Traceability and Electronic Test Reports "

Researchers will develop a standard data interchange template for transmitting a completely digital Material Test Report (MTR), improving efficiency in matching of documents to components and minimizing the risk of incorporating and operating an un-documented or out of specification component in a natural gas transmission system.

Project Description

The goal of this project is to develop a standard data interchange template for transmitting a completely digital Material Test Report (MTR) in compliance with API 5L Recommended Practice RP-5MT. The template should support modern data interchange technology used to transmit data securely across the internet. The data and processes must support methods of insuring authenticity of the resulting data originating at the manufacturing and supporting traceability back to the components that are associated with the MTR.

OTD’s projects (OTD 5.14.d Phase 1, OTD 5.14.d Phase 2) were key to the development of RP-5MT. Prior to this effort there were no criteria that identified and documented the data requirements needed for a fully digital inspection and test report document.

Today MTRs are delivered along with the components by truck drivers. The delivery of the inspection and test reports can be in the form of postal mail, courier services, or PDF files sent through email or FTP. Recommended practice API 5L 5MT meticulously detailed the data required for a completely digital material test report without imposing a specific standard defining any one of three Data Interchange Options between the pipe manufacturer and the customer.

Deliverables

Deliverables for this project include a data interchange model, filings required for a vote at API 5L committee for acceptance of interchange model, and a demonstration of one or more manufacturers using the model.

Benefits

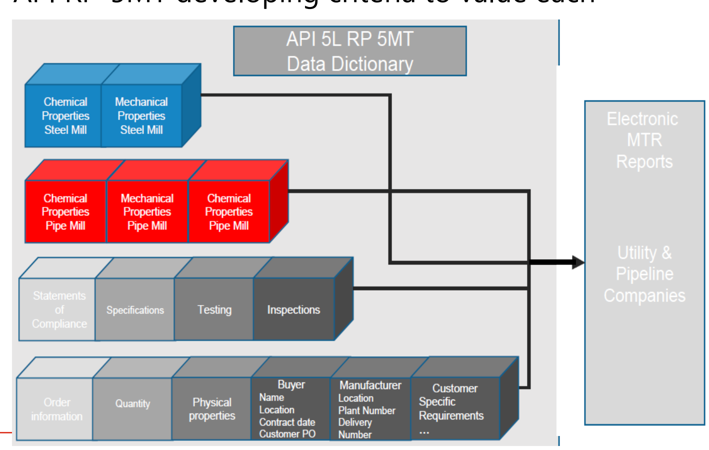
This project will determine the path to delivering a completely digital report for components under specification API 5L by creating the first digital interchange document delineated by RP-5MT. Since RP-5MT is a recommended practice, stock pipe is unlikely to be supplied with a digital MTR without a default digital interchange document for the manufacturer to follow. Completing this project will make the process of invoking a digital interchange document at time of ordering possible.

Utilities can expect to see a significant reduction in time required for manual matching of documents to components. This work is generally performed by experienced personnel when checking a component’s material’s mechanical and chemical properties for specification compliance. The technology developed by this proposal can minimize the risk inadvertently incorporating and operating an un-documented or out of specification component in a natural gas transmission system.

Technical Concept & Approach

Evaluate Interchange options building criteria for suitability

Research the data interchange options described in API RP-5MT developing criteria to value each



interchange option under consideration; 1. Delimited Text Files, 2. Web Services, 3. Electronic Data Interchange (EDI) including ANSI/ASC X12. The data dictionary that is included in RP-5MT will significantly assist this process and provide a common understanding the modeling processes that are needed to adequately define and assist in the selection of the interchange option.

Construct Data model from chosen interchange option

This task includes soliciting 5-10 sample MTR reports from different vendors and checking their data content against the RP-5MT for completeness. Develop and document a data model of the interchange option recording each data requirement, its relationship to other parts of the new digital report, observing the structure of data that is a single post to the interchange document or requiring an array of values were dictated by API 5L section 10 Inspection.

Pilot new interchange model with manufacturers

Work with one or more manufacturers to construct the needed scripts and processes to port data from current reporting programs used to print inspection certificates and reports.

Industry Acceptance (API 5L)

Continue relationship with API industry group RP-5M to update the 5L standards committee on work progress and establish relationships needed for incorporation into RP-5MT.

Interchange model documentation and reporting

This task is the preparation of the required filings for voting of the API 5L committee to incorporate the first revision of the data interchange option. The information will include the actual data model and accompanying documentation to fully define the entire model to be used to transfer MTR data digitally.

Results

After carefully reviewing the content of the API 5L Recommended Practice RP 5-MT and various methods of building a data transfer template, the team chose to use a more modern methodology to transfer digital data by formatting it in a JSON structure. This decision was chosen to assist component manufacturers, utilities, and pipeline companies in using more modern storage tools, analytical tools, and security architectures constructed for moving data over the internet. JSON has more industry support to secure the transmission of data, not by isolating it from alteration but by providing a means of assuring the originality of a document through electronic signature and electronic verification processes. The decision was made early in 2023 to use JSON as the foundation technology for modeling the second digital material test report template created by OTD funding. Work on the template was developed, reviewed by utilities, pipe manufacturers, and industry database consultants, and revised several times.

The project shared the first version of the template with a digital security company for comment and then incorporated their feedback in another round of revisions. The team used the resulting template from these reviews and consulted the API RP 5-MT data dictionary for a final content design check and finalized the template based on that review.

The template was used for converting paper MTR reports into digital models. This process was critical to build the data in the JSON model into the proper structures that are normally represented in a printed report. The final result enabled the delivery of digital MTR reports for an operator who piloted the model.

After the operators pilot was concluded, work continued on the template incorporating digital signatures and building a processing environment.

Status

The team is working to incorporate the entire process into an iOS application used to scan, evaluate, map, and log the required documentation for a typical natural gas transmission construction project.

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Project No. 8.22.d

Standardized Utility and Supplier Comanaged Inspection and Test Record Storage

Researchers will develop a pilot automated system that supports direct coupling of the inspection and test documentation using a machine-readable identification system, enabling field personal the ability to verify the required inspection and test documents are in the possession of the utility and automatically file inbound documents in the correct location.

Project Description

Currently there are no known systems that support direct delivery of the inspection and test documentation for new materials or components being installed on a pipeline system, to make this information readily available to verify manufacturing, testing, and inspection information. Many utilities perform these tasks through manual means, hand checking documents submitted by the manufacturer or distributor for proper traceability to the various pipeline components.

This project builds upon other OTD projects such as project '8.18.a Component Marking and Laser Etching Development' which establishes a barcode system for components. This project will provide a direct linkage from such a barcode scan to a document library enabling field personnel to verify that the required inspection and test documents are in the possession of the utility. Once the communications between a mobile client and a utilities document library verifies that the document is available, the mobile system will retrieve the documents for review and provide evidence that the properties of the components support the MAOP calculations.

Deliverables

Data collected through the pilot will be made available for review by the piloting utility, including a GeoJSON file to upload into their GIS system of record, and a final report.

Benefits

This project will create a pilot automated system that supports direct coupling of the inspection and test documentation using a machine-readable identification system established at time of manufacture, enabling field personal the ability to verify the required inspection and test documents for pipeline and components.

This project will also use the GS1 standard barcode index which, when scanned by the document system, identifies, and enables any inbound documents for automatic filing in the correct location in the document system. This process aids the utilities when adding the documents to the utility systems by the supplier and provides a predictable means of locating the document(s) through automatic means.

Verification of document availability by the utility or pipeline company is based on scans of machine-readable barcodes applied by the manufacturer or supplier to each component.

Wheatland Tube
2.375 .218 API5L X52 M PSL2 HFW PEB BAR

(01)01078669200009	Product ID
(11)210506	Date of manufacturer
(90)AA1196	Heat Number
(240)2	Component Type Pipe
(21)10001	Serial Number
(253)78669200282029656_Pipe	MTR Report
(416)0786692000008	location of manufacturer

Sample Product QR code and associated data

Technical Concept & Approach

Survey Utility Companies and Select Company for Pilot

Set up individual meetings with project sponsors to document and categorize inspection and test document storage systems. Once this information is collected, select a utility company for the pilot project. Build a copy of the utility's document management system on a cloud environment. Manage an identical pilot set of inspection and test documentation. Configure the pilot system with all document properties, security controls, and pilot documents simulating the actual production system.

Integrate existing mobile applications with pilot document system

Develop capability to process component barcode scans with the pilot document system. Verify that supporting documents are available from a component scan and can be displayed in the mobile document system. The pilot will also include a means of setting the status of the component for acceptance, rework, hold for documentation, or other conditions.

Conduct pilot project on an actual construction project.

Configure pilot document management system to mimic access requirements needed for a supplier to add documents to the pilot document system. Provide mobile application software for scanning each component as installed for service to the utility/ operator. The results of this work will create a cloud-based set of data resident in three or more databases available for export into the utilities system(s) of record.

Results/Status

The team reviewed the processes and storage managed by 3 utility companies. This review showed common practices using document management systems to store the records and index the records with multiple logical views of the documents based on their intended use. One utility was selected as the pilot utility for this project.

The team then designed and developed a document access system driven by process and regulatory requirements. This system provided tracking and traceability information on the component and supported automatic document acquisition in a protected environment.

The pilot system acquires tracking and traceability information from a GS1 formatted barcode on the component and collects the component's product attributes by accessing this information from GS1 Services (GDSN) Global Data Synchronization Network Services. All the pipe and fittings were identified and documented using GS1 application identifiers and product attributes. The pipe was also documented with e-signed digital material test reports and unsigned pdf MTR reports provided by the distributor.

Documentation, including the features captured during construction and material test reports (which contain the material test data for each heat of steel used to manufacture the pipe) were submitted to the utility upon completion of the pilot.

This project will include a new phase to allow the team to conduct two more pilots. The project/pilots are anticipated to begin in February 2024 and be completed by Q3 2025.

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OTD Operations Technology Development

Work Zone Intrusion Detection and Warning System

Researchers are investigating innovative solutions to protect employees and contractors working in situations where there is a possibility of work zone intrusion. They will provide a cost benefit analysis with recommendations to OTD members and provide feedback to solutions providers on any gaps discovered during analysis.

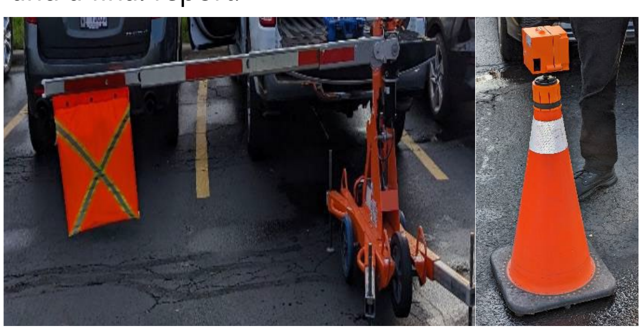
Project Description

In an effort to improve safety, the team is investigating innovative solutions and technologies to protect employees and contractors working in situations where there is a possibility of work zone intrusion. One scenario is unauthorized vehicles or pedestrians entering the work zone either accidentally or intentionally. According to estimates by the Federal Highway Administration, more than 20,000 workers are injured in road construction work zones each year with 12 percent of those due to traffic incidents. The growing issue of distracted driving emphasizes the challenges to work zone safety.

In this project the team will perform market analysis and testing of Work Zone Intrusion Alarm (WZIA) technology. The team will provide OTD members with a Cost Benefit Analysis including features and pricing of the evaluated solutions. The team will provide recommendations to OTD members and provide feedback to vendors based on any capability gaps based on industry needs.

Deliverables

The deliverables of this project will include the documented test results, a cost benefit analysis, and a final report.



Guardian SmartFlagger and Cone

Benefits

Increased adoption of WZIA technologies can improve safety for workers in the case of work zone intrusions. 12% of workers injured in road construction work zones are a result of traffic incidents.

Technical Concept & Approach

Research Current Work Zone Intrusion Alarm (WZIA) Technology

Conduct market research for WZIA devices and technology. Explore all industries that facilitate work zones with the potential for intrusion including electrical utilities, road construction, government municipalities, etc. Research will include contacting vendors for pricing data and the possibility of either an on-site or virtual product demo.

Evaluate Technology Currently Deployed by OTD Members

Set up meetings with project sponsors to determine if any WZIA technology is currently being used within their organizations and at what capacity/scale. Ideally this will provide insight into the decision behind the deployment of a particular solution and the pros/cons of a real-world application.

Vendor Demos and Field Testing

Finalize a list of products that have potential for practical deployment and will coordinate with vendors for either an on-site or virtual demo. If possible, purchase, borrow, rent, or receive demo devices/products for several of the selected products and conduct field testing. Project sponsors will be consulted for testing scenarios and the potential for participation.

Cost Benefit & Gap Analysis

Conduct a Cost Benefit Analysis including product pricing, features, and practical application scenarios. In addition, identify any potential enhancements that could make current solutions more beneficial to the natural gas industry use cases. This will provide project sponsors interested in deploying WZIA technology with actionable information and the ability to make the best decision for their organization, as well as feedback to Vendors on any gaps between their solutions and the natural gas industry's needs.

Results

The team developed matrix of technologies to provide a central repository of available products and their features and capabilities. Market research was conducted across the work zone safety space to identify new products that differ from traditional passive prevention technologies such as cones and lights. The team leveraged research papers from the transportation industry and feedback and input from OTD sponsors to add items to the matrix and discuss capabilities/features.

Products were categorized into passive prevention, alarm and smart technologies, and traffic control systems.

The sponsors selected their top three technologies of interest from the matrix for further evaluation, which included Pi-lit Smart Flares, the Traffic Worker Alert System (TWAS), and the Guardian SmartFlagger. The team acquired samples from vendors or purchased products for an on-site demonstration. The report provides a detailed analysis of each device, highlighting its features, advantages, and disadvantages.

The primary test consisted of a driver with no prior expertise or project knowledge driving through a course, where each pass had a different configuration of safety devices. After every pass, the driver was asked what they noticed, how much the safety setup increased the driver's awareness if the devices held their attention, and what their response would be if passing through a "real world" work zone.

The team identified that there is a lack of products suitable for daytime use. Most products feature bright lights, which are more effective after dark.

The team determined that there is an opportunity to have state DOTs require all work zones to interact

Pi-lit Smart Flares Deployed

with navigation systems. The current obstacle is that not all the major navigation systems are partnered with technologies like Pi-Link, Guardian SmartFlagger, etc. The tests done by the team showed that the concept of communicating with the navigation applications does work and has the opportunity of alleviating the risk by diverting traffic and prewarning drivers.

There is an opportunity to enhance safety for workers if the DOT recommends or encourages that all work zones must interact with navigation systems to aid in alerting motorists at a certain mile range before the work zone.

Drivers' psychology was an area that the team identified as warranting more research. Specifically, there is concern that while the most effective warnings come through these applications, it may result in "warning fatigue."

Status

A final report has been released to OTD members in December 2023.

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Pipe Bridge Inspection/Design using LiDAR Drone-based Inspection

Researchers will evaluate the entire process of using drones to conduct above ground natural gas pipe bridge inspections. This will include selection of drones, evaluation of collected data, review of analysis software, and field testing.

Project Description

This project will evaluate the viability of performing aboveground natural gas pipe bridge inspections through the use of Unmanned Aerial Vehicles (UAV). The team will assess the process of using drones to inspect hard-to-access areas alongside and under bridge structures while collecting high-resolution photos, videos, and rich LiDAR point clouds.

Data products can be used in real-time while performing on-site inspections or post-process reviews, depending on inspection requirements. The team plans to collect data in these formats from a drone, analyze the quality of that data, and produce products that match or exceed current expectations for pipeline maintenance or atmospheric corrosion control. The team will build data collection workflows and identify productivity gains over existing methods to help a utility understand the most efficient and repeatable approach to performing necessary inspections.

Deliverables

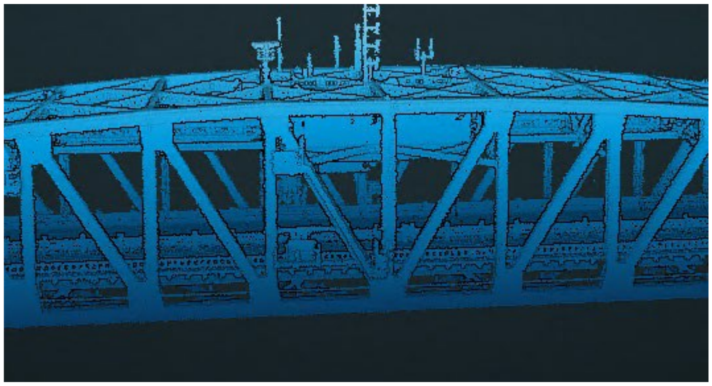
This project will deliver detailed documentation in the form of a report on the hardware, software, and workflows used to evaluate and test drone-based pipe bridge inspections. Results will also be shared in the form of photographs, videos, and a webinar with the project sponsors.

Benefits

The added value of using drones to perform pipeline bridge inspections comes from safety, efficiency, and equipment cost. Traditional assessments are time-consuming and can lengthen project schedules. Ladders, scaffolding, snooper trucks, or even human rope access services all take time to set up, and the solution can be potentially unsafe. These traditional inspection techniques cannot cover as much territory as a drone can in a fraction of that time and do not result in a digital record that can be used for real-time or post-inspection review. Drone data collection can consist of photos, videos, and LiDAR point clouds that can be utilized for 3D modeling, rendering, and frame or stress analysis of the bridge and the pipe itself. These products can also act as a historical repository to compare multi-year inspections and check for the quality of the pipe and its attachments.

According to federal regulation code CFR 192.481 Atmospheric corrosion control: Monitoring, onshore pipelines need to be inspected at least once every three years. Considering utility companies may have hundreds of pipe bridge locations to review, the industry requires a simplified and more efficient process to help ensure worker safety and reduce operating costs for these inspections.

LiDAR Based Drone



LiDAR Based Scanned Bridge Example

Technical Concept & Approach

Product Evaluation and Testing

- Identify specific drones and drone solutions that meet the needs of pipe bridge inspections, including vendor outreach and potential demoes
- Evaluate the data products that these drones and drone solutions produce specific to LiDAR, video, and high-resolution imagery
- Evaluate software that meets the needs of reviewing the drone collected data
- Develop a workflow for using the appropriate software to derive valuable data for pipe bridge inspections and changes in pipe dimensions

Selection of Drone Technologies

- Rent or purchase the selected drone, or drone solution
- Purchase necessary software for LiDAR and imagery review analysis

Field Evaluations

- Test drone data collection on aboveground pipe scans at GTI
- Test data analysis, data review, and data extraction from drone-based collected products
- Perform drone-based pipe bridge inspection(s) on a utility sponsor's infrastructure (a minimum of one project site)
- Perform analysis on pipe bridge inspections at select project sites
- Document best practices and workflows from field evaluations

Results

The team has completed Market research to identify potential drone technologies and service providers. These efforts identified drone technologies that include video and LiDAR capabilities, and identified estimated costs and associated software/data processing capabilities necessary to analyze the results.

The team facilitated a workshop by Skydio in Southwest Gas' territory. This workshop included Skydio flying under a bridge where a gas main was installed and inspection of a steel gas main that traversed the side of a large foothill. The effort resulted in the sharing of data products that will be used as part of technology evaluation.

Status

The team is focused on completing the selection of drone technologies and holding scheduled field demonstrations of selected technologies in 2024. The project is expected to be completed in Q3 2024.

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Augmented Reality (AR) Technology to Enhance Field Operations

Researchers will evaluate the current state of AR technology for it's utility to the natural gas industry, focusing on it's ability to assist in performing locates, leak surveys, as-builts/planning, construction, providing situational awareness, and capturing 3D scans.

Project Description

This project will evaluate the impact of utilizing Augmented Reality (AR) technology to enhance and assist field crews as they conduct gas operation activities. The results of this assessment will provide gas utilities with a better understanding of how leveraging AR technology can help optimize gas-related operations.

The Microsoft HoloLens (now in its second iteration with HoloLens 2) provides a powerful experience and, when paired with the correct application, a user can interact with a gas utility's spatial data in the field. The HoloLens 2 reduces the bulkiness and serves as a significant upgrade from the original HoloLens for field use.

vGIS Open Trench Scan

In recent years, both Google and their Android Mobile Operating System and Apple with their iOS Operating System have spent considerable effort developing ARCore and ARKit. This allows developers to build powerful AR graphics into mobile applications that run efficiently on Android and iOS-based smartphones and tablets.

The project seeks to evaluate the current state of technology and determine the best applications for the natural gas industry. It will build on previous work of past projects using Holo Lens:

- SMP project 22111 Holographic Computing in the Natural Gas Industry
- OTD project 8.18.c Microsoft HoloLens Platform Enhancement & Pilot Project
- OTD project 8.20.b Augmented Reality Technology Evaluation

Deliverables

A report outlining the workflows used to evaluate the AR technology's functionality, which will highlight the lessons learned from each selected use case.

Benefits

Gas utilities can take advantage of new developments in AR-capable hardware devices by leveraging the high-accuracy spatial location data they are collecting (horizontal and vertical positioning) to provide a more accurate and interactive real-world version of their data.

Using AR technology may provide users with a more efficient and improved ability to visualize and

HoloLens 2 in use with Survey Pole with High- Accuracy GNSS Receiver

interact with their geospatial data. At its core, AR technology overlays holographic images representing the location of geospatial data, or other types of information, to the user through a headset, tablet, or smartphone device. Recently, AR applications have begun incorporating functionality to pair with a high accuracy GNSS receiver. This integration will help maximize the spatial accuracy achieved by using an AR solution. This produces a more accurate visual representation of a utility's spatial data while allowing field workers to visualize the gas system as it is buried underground. Additionally, this integration will allow users to capture high accuracy data out in the field.

Some examples of uses cases for the natural gas industry are:

- Perform Locates - Ability to identify the location of gas assets for excavation, mark-outs, and general navigation to a particular asset.
- Leak Survey - Ability to identify the location of gas assets to support leak survey/leak investigation activities.
- As-Builts/Planning – Visualize the proposed location of assets based on engineered drawings.
- Construction – Visualize various environmental data set layers during construction (i.e., Geological layer).
- Situational Awareness – Provide additional 'situational awareness' by connecting users with their utility GIS data to access attribute data and other information linked in the GIS.
- Reality Capture – Ability to capture 3D scans (LiDAR) and/or view them in an AR environment (i.e., open trench scans)

Technical Concept & Approach

Identify Field Operation Activities

Identify specific gas-related field operation activities that can be conducted and enhanced by leveraging the available functionality of AR technologies. Examples of use cases for evaluation may include Data Collection, Performing Locates, Leak Survey/Investigation, As-Builts/Planning/Construction, Reality Capture/3D Scanning, Situational Awareness.

Develop and document criteria to evaluate the AR technology, including optimizing work efficiency, enhancing work experience, providing increased safety, positive field user's experience.

Selection of AR Technologies

Work with project sponsors to determine which AR technologies they are interested in evaluating. The focus will be on the vGIS AR software solution; however, other AR technologies can be assessed if requested explicitly by project sponsors. The chosen AR technology will consist of hardware, software, and supplemental technologies to support the AR systems (GNSS Receivers, Survey Equipment, etc.).

Field Evaluations

Conduct real-world field evaluations of the selected AR technologies (hardware and software) to validate the full extent of their capabilities and usefulness when conducting the identified field operation activities.

Results/Status

The team has developed the use case and basic test plan and executed pretesting. Software options have been evaluated and a software solution was selected. The team has started field testing and will be concurrently conducting data analysis. The project is expected to be completed in June of 2024.

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Project No. 8.22.I

Legal Challenges and Implications of Sharing GIS Data with 3rd Parties

Researchers will be developing templates for legal documents to help overcome common barriers to data sharing found in OTD projects. Researchers will interview key stakeholders to ensure that these documents meet their data sharing needs.

Project Description

The goal of this project is to investigate the legal challenges associated with utilities making GIS data available for 3rd parties, develop template NDA's and terms and conditions, create a vetting process, and suggest alternatives to traditional methods for setting up agreements and sharing data.

Technology driven projects often require a reliable dataset to demonstrate its effectiveness. Since various stakeholders are involved in project that require information sharing, it is important to understand what key areas of protection and security are needed to gather data that will be used to better understand an operators system, and provide recommendations to potentially enhance safety and their operations.

Deliverables

This project will produce legal templates for an NDA, Terms and Conditions, and a Questionnaire. It will also deliver a risk matrix and a final report.

Benefits

OTD commonly works with utility companies on projects that require the exchange of digital data. The process of setting up NDAs, filling out questionnaires, and the back and forth between legal teams is challenging. Often an agreement is never reached, and the data exchange does not take place. If an agreement is reached, the process can cause project delays of up to six months to a year.

Ultimately the end user of each utility is the one that loses out. The research and applications resulting from more robust digital data exchange will lower the cost of pipeline operations, improve first responder effectiveness, lower carbon emissions, and analyze the logistics of the introduction of hydrogen into pipelines and the overall market. The ability to share data securely and effectively is paramount with current technology trends and the outside expertise needed to capitalize on them.

Technical Concept & Approach

Investigate related industry data exchange criteria and protocols

Investigate and report on similar critical infrastructure and energy systems, define and document common workflows of sharing data across stakeholders, their partners, and the safeguards and protocols in place to protect the exchange.

Establish risk matrix for utility data exchange with 3rd parties

Develop a risk matrix tool to list and categorize the types of data and establish a level-based sensitivity rating.

Develop NDA and Terms and Conditions data exchange templates

Engage OTD members teams and legal counsel to determine concerns with sharing data. Develop template NDA's, terms and conditions, and a questionnaire.

Establish acceptable vetting criteria and process

Work with OTD members to determine a viable process for vetting companies requiring utility GIS data. The vetting process will be tied to the sensitivity rating levels established in the risk matrix.

Develop implementation plan for a data exchange hub

Offer a plan of action for creating a data exchange hub in which OTD would perform the vetting process established in this project, set up NDA's and legal agreements, store and secure the GIS data, make the data available to the 3rd party, and decommission the data and accounts once the project period ends.

Results

Interviews were conducted with representatives from six organizations to discuss their data-sharing processes and challenges. Interviewees indicated a wide range of data sharing pathways and decision points. From the interviews it was determined that the primary types of data shared include line locates, leaks and damages, miles of main/services, and emissions analytics and reporting. Data-sharing with contractors is relatively easy and has not been a pain point. Major concerns uncovered in the interviews include:

- Concern was expressed over dating sharing with municipalities due to FOIA laws.
- Concerns about data end-use and interpretation (e.g., emissions levels of confidence, line location accuracy).
- The burden of data requests from regulators

Status

The team is focused on hosting a series of workshops o facilitate collaboration and ensure that the project is focused on sponsors' needs.

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Exodigo

Researchers will evaluate the capabilities and performance of Exodigo's non-intrusive subsurface mapping platform to locate underground infrastructure and compare this technology with other methods.

Project Description

This project will evaluate the capabilities and performance of Exodigo's non-intrusive subsurface mapping platform to locate underground infrastructure. At its core, the solution combines multiple sensor types with artificial intelligence (AI) to provide a digital, geolocated 3D representation of the underground assets. This unique application allows the Exodigo technology to detect a wide range of underground materials without utilizing several pieces of locating equipment.

Over the past couple of years, OTD has conducted various projects to evaluate different technologies designed to map and locate underground utility infrastructure. These projects assess currently available methods or have attempted to combine multiple methods via associated data fusion techniques. The Exodigo solution provides an opportunity for the team to evaluate another platform against the extensive library of locating technologies previously tested at OTD.

Deliverables

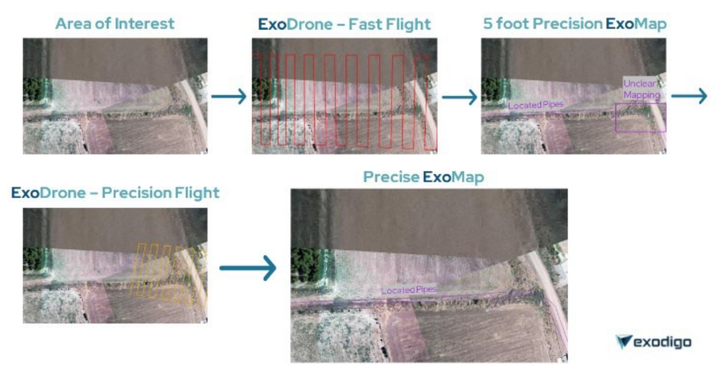
This project will develop a testing matrix to evaluate the Exodigo technology, which will be applied and updated for any potential field demonstration and draft a report documenting the results of the Exodigo baseline evaluation taking place at a pipe farm.

Benefits

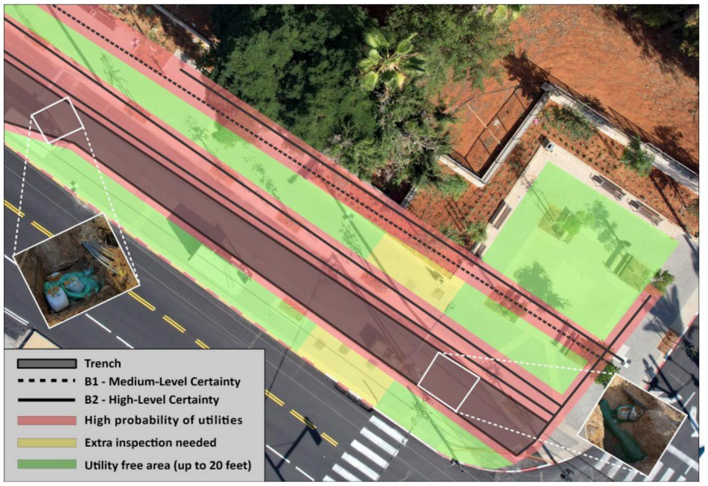
The ability to map and locate existing underground infrastructure supports damage prevention for gas utilities. Every year, millions of dollars are spent on excavation activities to uncover and locate underground facilities before any installation or repair. These are costly and timely activities.

A key benefit of Exodigo's non-intrusive solution is its ability to cover a large area in a short time. Additionally, because the solution is designed to leverage multiple sensor types, it can quickly and accurately detect a wide range of underground facilities in a congested area without swapping out for different pieces of locating equipment.

The solution is also available in both aerial and ground-based platforms so that the Exodigo solution is optimized to perform in both rural and urban environments. Exodigo can provide users with a GIS file of the scanned area containing the horizontal (x,y) pipe location, the vertical (z) pipe location (if possible), plus attribute information such as material type. The data collected and output during this process can be integrated into a GIS system as 2D, 3D, and potentially 4D features, providing exceptional value and knowledge of their infrastructure to the gas operators.



Exodigo Drone Locate Survey



Exodigo Locate Survey in a Congested Area

Technical Concept & Approach

Baseline Evaluation of Exodigo Platform

Conduct a baseline evaluation of the Exodigo solution on underground infrastructure already installed and located in a pipe farm. Using both ground-based and aerial-based platforms, Exodigo will perform scans of the pipe farm and provide the team with the results of these locating activities.

Use the Exodigo results to perform a comparative analysis of the Exodigo solution against other locating technologies (3D scanners, EM locators, in-pipe mapping and locating tools) that OTD had previously evaluated on this underground baseline pipe system.

The team will also develop a testing matrix to evaluate the overall performance of the Exodigo platform to include variables such as:

Duration – How long does it take to complete a survey? How much area can be covered? Aerial-based vs. ground-based.

Locational Accuracy – Horizontal and Vertical positioning

Material Type Accuracy – How accurate is it at detecting material type?

Congested Areas – How does it perform in heavily congested areas?

Missed Locates, or False Positives – How accurate is it at locates? Does it miss any utilities or produce any false-positive results?

Field Demonstration and Analysis

Conduct a field demonstration of the Exodigo technology with project sponsors, demonstrating the technology under various field conditions.

The field demonstration will allow the team and Exodigo to collect feedback about the technology and determine its usefulness and feasibility within the gas industry. It will also enable Exodigo to explore other use cases that can serve the gas industry by leveraging different types of sensor technology.

Results

The team conducted an initial baseline evaluation of the Exodigo technology. On a pipe farm. There were two locations selected for this baseline evaluation: 1) a control environment where the team knew the location of the underground pipes with a high-level of accuracy, and 2) another site where there was no knowledge of what types of pipes existed.

The team then ran analysis of the comparison of these scans to the known underground utility locations. Data were compared in the horizontal direction and visualized in the vertical direction with average accuracy differentials recorded for the horizontal. The results of this analysis were presented to the sponsors.

Status

The team is focused on testing at a second demonstration site in different conditions, topographies, and pipe types.

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3D Monitoring of Terrain Over Pipelines

Researchers will evaluate new elevation datasets and develop a refined terrain model in order to keep natural gas infrastructure depth measurements up to date as the earth's surface changes.

Project Description

This project will evaluate the ability to locate and acquire data for creating more up-to-date and accurate elevation models of the earth's surface near underground pipeline infrastructure.

The earth's terrain changes regularly, but mapping systems do not account for these rapid changes in the elevation models they may provide. Elevation models used in mainstream GIS platforms may visually misrepresent accurate underground pipelines because they are outdated or were not built with accurate data from the start. This problem makes it difficult for end users to trust the depth to pipe values that were recorded in the past when performing preplanning exercises or digging activities.

Utility companies that want to, or already do, collect the depth of cover on their pipelines in GIS could greatly benefit from a method that would keep that depth accurate to date. The datasets needed to generate these more accurate models may be publicly available or may have a cost based on the vendor and their acquisition method. In addition to these options, some utilities may already fly their pipelines for High Consequence Areas (HCA) analysis or other studies where the needed product is already being created or could be generated at an additional cost.

With these new datasets processed into revised terrain models, the team will define a process to update existing depth of cover values stored in GIS respective to the changes that have occurred over time to the ground surface.

Deliverables

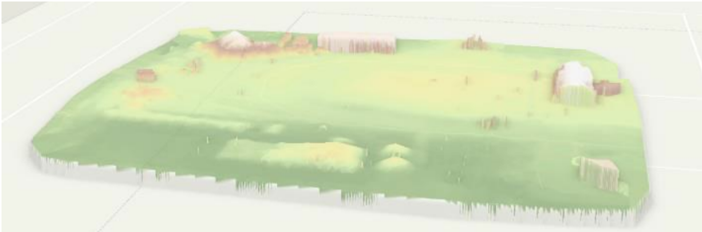
The main project deliverables will be:

- A Matrix of available Digital Elevation Model datasets, including acquisition type, data acquisition costs, and update frequency
- Documentation of data workflow, including project set-up, data collection, data processing, and results
- Documentation on proper procedures for updating existing depth of cover attributes in a current GIS dataset
- A Final Report.

Benefits

Today's utility industry encompasses the advanced capabilities to collect high-accuracy data for gas components in an open trench. Additionally, newer handheld electromagnetic (EM) and ground penetrating radar (GPR) utility locate tools joined with high accuracy GNSS receivers have similar capabilities but with slightly less accuracy on a buried pipe and usually focus specifically on the pipe itself. Both options can record the depth of the pipe below the ground surface and apply a time stamp as to what that depth of cover was on that given day of data collection.

Moving forward from that date does pose a problem as the trust and reliability of that depth value grows weaker, the ground shifts, and the data soon becomes outdated. If utility companies are investing in collecting this data (i.e., x, y, and z values), they would easily benefit from a way to keep it current. Having up to date depth measurements would be valuable to the utility company performing pre-planning and construction activities. Other agencies



Elevation Model Generated from a Drone flight Compared to an Older Elevation Model

that may work around the natural gas pipeline infrastructure would benefit equally.

Technical Concept & Approach

Data Acquisition Evaluation

Research available open-source data options available to the public for digital elevation model creation. Research paid services for digital elevation modeling data – this may include, but is not limited to, satellite data, airplane collected data, or processed data available for download. Engage in product demonstrations for paid services to review sample data from these types of providers. Document these sources and their path to acquisition. Evaluate the viability of acquiring a sample GIS dataset that includes a depth of cover attribute from project sponsors.

Digital Elevation Data Selection

Select the proper digital elevation dataset(s) based on the various options (i.e., satellite, plane, etc.). Purchase the proper datasets directly or set up a subcontract with the appropriate vendor(s) to learn how to acquire the data from the vendor(s) storage locations. Review acquired data and set up a proper localized data environment for analysis.

Desktop Data Processing

Set up a localized environment for data processing of acquired digital elevation data. Create digital elevation models based on acquired datasets. Document proper data processing steps for all elevation datasets acquired. Develop a process for utilizing newly generated elevation models to update the previously recorded depth of cover within the acquired GIS data. Automate geoprocessing steps for elevation model creation and depth of cover calculations where possible. Document all the procedures necessary for project sponsors to perform the analysis internally.

Results

The team created a data matrix of free and paid elevation data models to be evaluated for this project. Elevation data sources were identified to download specific datasets for two geofenced study areas in New York City and Oakland, California. These sections were selected because multiple datasets, including contours, digital elevation models, and LiDAR, were available for free download and because OTD had some in-house data encompassing elevation data on gas assets respective to these areas.

The team used these free data sources to design a workflow and documentation for applying a new underground elevation value to existing assets based on the existing depth of cover attributes located in the sample GIS datasets. The team also interfaced with commercial satellite imagery providers to review products in the Digital Elevation Model and/or Digital Terrain Model market space.

The team uncovered the potential of acquiring satellite based DTM data from the Airbus Pleiades or the Maxar World View satellites and established contact with a reseller of the data products generated from these sources under the name Apollo Mapping. The team determined that OTD could acquire 5- meter DTM raster imagery for a minimum of 100 square km. In tandem, the team documented its initial workflow design for processing LiDAR and DTM files in Esri ArcGIS Pro.

Status

The team is currently focused on reviewing final aspects for documentation around converting contour and LiDAR data into usable Digital Elevation Model and/or Digital Terrain Model datasets.

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Mapping Inside the Fence with ArcGIS Indoors and Utility Network

Researchers will evaluate the feasibility of mapping pipeline facilities 'inside the fence', such as compressor stations and meter sites, to increase the effectiveness of risk models, pipeline integrity management, the ability to perform MAOP (Maximum Allowable Operating Pressure) validation, and enhance records to ensure these records are traceable, verifiable and complete (TVC).

Project Description

This project will evaluate the feasibility of mapping pipeline facilities that are "inside the fence" and not historically mapped in GIS data models. The team will evaluate the process and impacts of mapping facilities in the Utility Network data model and how ArcGIS Indoors can assist in the process. Additionally, the team will perform industry research with other organizations to assess any upcoming changes to regulations that would make mapping facilities a requirement.

Deliverables

The results of the feasibility analysis will be summarized in a final report.

Benefits

When pipeline companies build their GIS data management systems, facilities such as compressor stations, meter sites, launchers/ receivers, etc., are mapped as point features with the pipe segment running through them. Some companies do track the valves inside the facilities but stack them on top of each other.

By enabling a detailed representation of the piping, this technology will increase the effectiveness of Risk models, pipeline Integrity Management and the ability to perform MAOP validation (TVC).

Additionally, using technology such as ArcGIS indoors, operators can tie CAD documents and 3D models directly into GIS systems. With PHMSA's increasing emphasis on MAOP validation, the pipeline industry also needs to prepare for potential future modifications to the requirements of data management and reporting within facilities.

Technical Concept & Approach

Utility Network Implementation and Data Model Research

Implement Utility Network and test the ability to fully model facilities. Focus on identifying what data models are suited to store facilities data, what modifications are needed, and what limitations exits.

Facility Data Collection

Identify potential facilities for mapping. Collect existing documentation on the facility and any required field data collection. Potential facilities include compressor stations, meter sites, launcher/ receivers or any facility that is traditionally stored as

point features in the GIS data model.

Modeling and ArcGIS Indoors Evaluation and Testing

Work with a project sponsor to obtain a 3D piping model of a real-world location. Use a platform, such as ArcGIS Indoors and/or others, to connect the model to GIS and the utility network model. Investigate the capabilities of ArcGIS Indoors, or other software, and its ability to model compressor and other indoor facilities to connect the network of pipe inside the station to the suction and discharge lines that are already mapped.

Results

The team worked with project sponsors to identify challenges, and where additional insight or information may aide operators with respect to mapping facilities and components inside the fence. Every organization is at different stages of Mapping Inside the Fence and the use of the Network Utility model. A GIS Analyst was brought onto the team and high-level research was conducted on the Utility Network model.

Status

The team is currently working with sponsors to collect necessary information and explore integration to the Utility Network and other GIS models.

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SSR Correction Service For GNSS Utility Mapping Applications

Researchers will develop a mapping service which incorporates satellite SSR correction data into UTTO Pathfinder and vLocateMapper. This will improve the efficiency of locate processes and improve data accuracy, leading to reduced costs and reduced damage to infrastructure.

Project Description

Global navigation satellite systems (GNSS) have been designed for applications other than the natural gas industry, such as agriculture, transportation, government, natural resources, etc. Designing a solution specifically for needs related to buried facilities and infrastructure would increase their effectiveness and ease of use.

Traditionally, the devices require an engineering approach along with a steep learning curve limiting the practical deployment in mapping and relocation processes. One of the limitations of existing high-accuracy GNSS devices is the need to connect to a local RTK base station to obtain the required correction signal. The station should typically be within 7 km of the user and requires an IP over cellular or local radio connection to the RTK feed. The user must constantly switch stations and select new feeds and port numbers when moving to new work site locations.

The advantage of SSR (State Space Representation, also known as PPP-RTK) is the correction signal is obtained over the GNSS satellite feed, simplifying the end-user experience while delivering fast fix and 3-6 cm correction signals.

This project aims to develop a mapping service using SSR correction data (via L-Band satellite channel) to simplify the task of accurately capturing buried asset points (3-6 cm accuracy) and remove the need for RTK or other augmentation services.

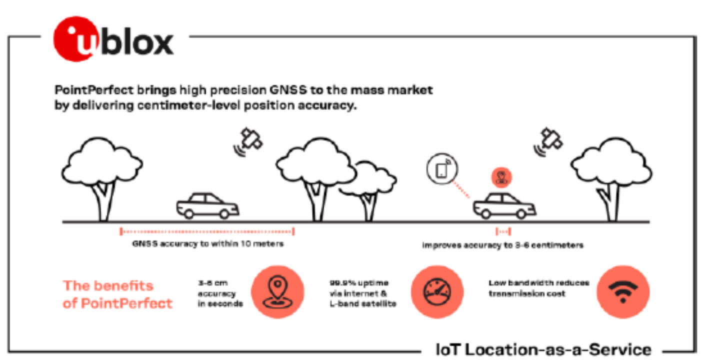
Efforts will be focused on developing and integrating SSR functionality into UTTO's Pathfinder EM locator and UTTO's vLocate Mapper to permit OTD and select members to field test and evaluate. The system will provide a service provided by U-Blox's PointPerfect SSR platform. The system is advertised to have a better than 6 cm accuracy with a time to first fix of less than one minute.

Deliverables

- A customized prototype incorporating SSR correction into UTTO Pathfinder and vLocate Mapper.
- A cloud-based UTTO server customized to the team's needs with Member account access to view uploaded data.
- Field testing results
- A final report

Benefits

This project will increase the efficiency of the locate processes and improve data quality. Any improvements to data on the location of buried assets will make working with and around those



PointPerfect by U-Blox

assets more efficient and reduce inadvertent damage to those assets. These benefits also extend to emergency response capabilities which increases safety.


UTTO's vLocate Mapper (left) and Pathfinder EM

Technical Concept & Approach

Development

Develop SSR based on UTTO's new device hardware (GNSS antennas and circuit boards) and firmware. Develop new server and mobile app software to transport collected field data to the end user's UTTO Cloud account. IPEG will supply hardware and software to OTD for testing.

Field Testing and Analysis

Perform prototype testing at a pipe farm testing facility with optional one or more pilots at sponsor locations, including development of a test plan, performing testing, and analyzing the results.

Results

The team successfully developed and tested a mapping device that uses SSR correction data (via L-Band satellite channel) including hardware, software, and firmware components.

Status

The team has started field testing at a pipe farm.

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OTD
Operations
Technology
Development

Optically Clear Transmission Pipe Coating

Researchers will develop a transparent coating product and application procedure that protects natural gas transmission components from corrosion and enables the application of machine-readable identification, barcodes.

Project Description

OTD project number 8.18.a.2 developed a laser engraved barcode for part identification. Existing coatings designed to protect components from corrosion would obscure this marking making it unreadable. This project seeks to develop a coating product and application procedure that protects natural gas transmission components from corrosion and enables the application of machine-readable identification, barcodes.

A second objective is to apply additional identical barcodes at some interval along the length of the pipe under the coating system during the coating process. Duplicate barcodes are applied to support sectioning the pipe one or more times for different construction lengths and store unused pipe segments with confidence that the identification information is available from a simple barcode of the remaining pipe.

Deliverables

The main project deliverables will be a final report that summarizes procedures for transferring data reliably and securely from barcodes on ID of pipe to OD of pipe prior to coating, and an assessment of one or more coating system(s).

Benefits

Identification of piping system components has traditionally used human readable identification. This is applied through a variety of means with stenciling, printing or metal stamping human readable identification. In the event of a project being delayed or cancelled, pipe is often resold. This pipe is most likely stored outdoors, and its identification information is often lost due to sun fading the inks, paint from multiple forms of atmospheric attack. Encapsulating a laser engraved identification barcode in the coating system can extend its resilience for reading scanning, permitting reading in the future, and limiting the risk of scrapping a useful product simply due to loss of track and traceability information.

Technical Concept & Approach

The primary tasks for this project include:

Coating System working group

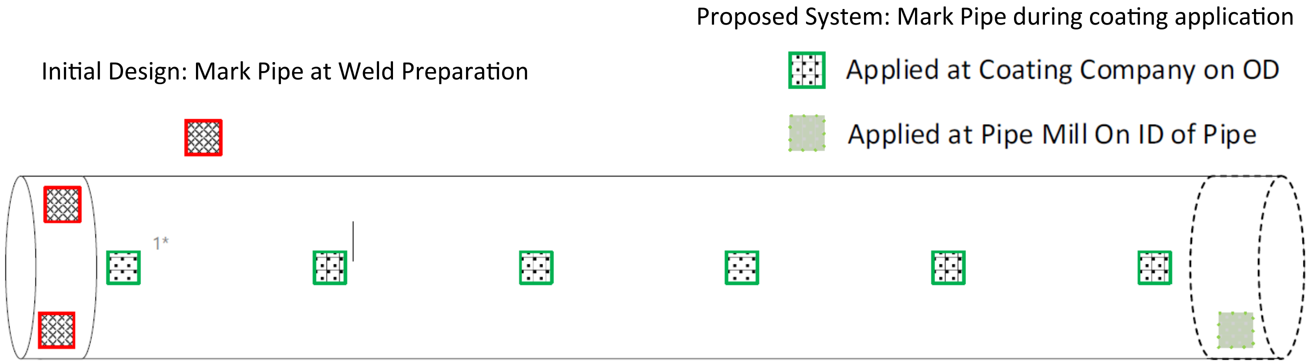
Conduct discussions with coating system manufacturers for potential candidate coating systems for reformulation. If there are no suitable coating systems then discuss time, schedule, and cost to build a new coating product, test variants of that product creating possible new coatings.

Coating System Development

Conduct discussions with coating system manufacturers for potential candidate coating systems for reformulation. If there are no suitable coating systems then discuss time, schedule, and cost to build a new coating product, test variants of that product creating possible new coatings.

Application procedures, processes, and testing

Work with coating companies and pipe manufacturers to evaluate different protocols for marking the pipe on both the ID and OD and the methods of transferring the content from a scan of a barcode on the ID of the pipe or fitting to the OD.



This includes developing a cleaning and laser engraving processes for trial and to ensure integrity for the transfer of the mark from the ID to OD of the component and establishing test environments to perform laboratory development of cleaning, ID laser engraving, barcode copy and transfer processes to carry barcode data to OD.

Results

The team researched several coating systems for the potential to create a clear coating by removing the pigment.

One epoxy vendor expressed interest in the engraving process being applied to the surface of their finished coating and suggested that they might develop a clear overlay that would cover the engraved service where the barcode was placed, serving as a seal to corrosion elements and provide UV protection.

The team provided information to the coating manufacturer for the preparation of test plates to start the preliminary work of developing engraving procedures and processes to learn how to engrave fusion bonded coating systems without compromising the corrosion integrity of the coating.

An additional coating system was brought to the attention of the team, which is used to protect small-diameter piping. Metering and control systems at regulator stations and city gate purchase points all contain small-diameter piping and components and are difficult to mark. Powder coat applied to small-diameter pipe and pipe fittings (elbows, tees, reducers, bushings, nipples, and other specialty fittings) is becoming more common, being applied prior to the sale of the component. The team held three meetings with the coating company and has received sample plate and pipe fittings to investigate engraving barcodes into the coating.

Status

Testing was delayed due to the upgraded control board being significantly damaged during shipping. The control board is at the manufacturer for repair. The team anticipates being able to start engraving the test plates and fittings in 2024.

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Developing Routing Solution for Leak Survey

Researchers seek to improve the efficiency of leak surveys through route optimization. The team will evaluate existing practices as well as potential software solutions.

Project Description

This project seeks to improve the efficiency of walking and driving leak surveys conducted by utilities by using geospatial data. The team will explore current methods used for walking and driving leak surveys and then will evaluate existing tools for optimized route planning or develop new capabilities if existing tools do not meet the needs for this task. The team will also consider that qualified personnel are required to revisit a known leak location for leak rate testing and optimize routing for this secondary task. Leak classification levels, expiration dates on previous leak surveys, and spatial proximity of leak investigation crews to these lines and leaks will also be factored in for efficient routing purposes.

The team will communicate with industry-based technology providers to determine if routing solutions to efficient leak survey assignment or revisitation routing already exist. If one does not exist, then a solution will need to be developed to meet the needs of interested project sponsors. The team will evaluate existing operations or systems that project sponsors use today to generate leak survey crew assignments or the assignment of revisiting previously identified class two and class three leaks. The team will investigate how these systems can integrate with other software platforms to handle the assignment and routing of those leaks efficiently and promptly.

Deliverables

The main project deliverables will be:

- A matrix of available route optimization platforms/tools, costs, and custom development possibilities
- Documentation of data workflow, including project set-up, data upload for route optimization, route optimization processing, and results
- Documentation of proper procedures for project sponsors to use selected route optimization platforms/tools
- Final Report

Benefits

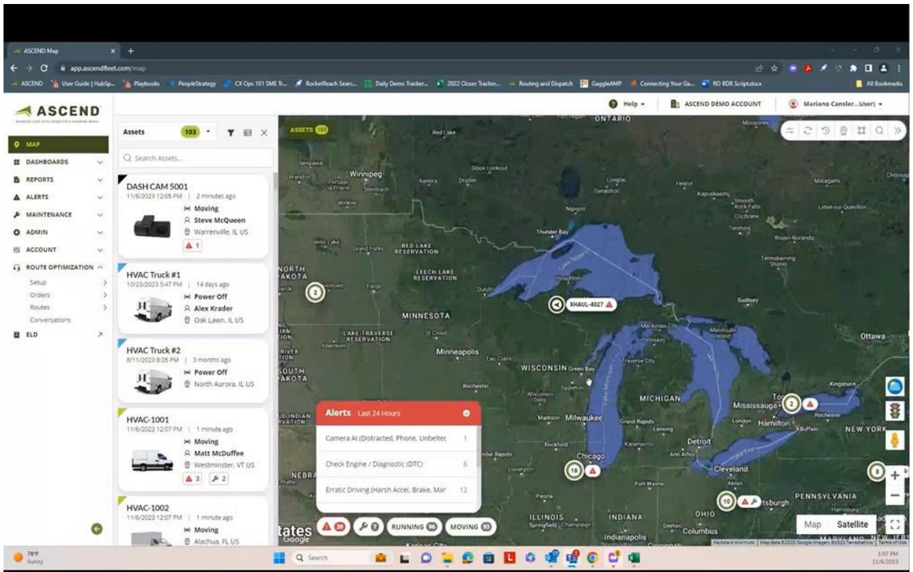
This project has the potential to improve efficiency and reduce the cost associated with leak surveys and revisiting previously identified class two and class three leaks for leak rate testing. Using optimized route planning personnel can be more efficiently directed to the next leak evaluation or rate testing location. Additionally, have digital geospatial records of leak surveys over time could give valuable information and statistics that could be used in the future.

Technical Concept & Approach

The primary tasks for this project include:

Evaluation of Leak Survey Workflows and Route Optimization Platforms

Consult with project sponsors on current leak survey practices and determine the hardware and software currently being used to perform leak surveys. Research available third-party software and tools for route optimization and, if needed, the potential for development of route optimization tools on existing platforms. Document these platforms and custom solutions and their path to acquisition or development. Work with project sponsors to determine the viability of acquiring a sample GIS dataset that includes distribution lines and classified leak locations.



Screenshot of Ascend portal demonstrating vehicle tracking and reporting system.

Route Optimization Platform Selection

Select route optimization software or add-on component from analysis conducted in the previous task. If the proper platform does not exist, document the needed functionality for custom tool design and/or modifications to existing tools. Purchase the route optimization platform or create custom/modified tools to perform the optimization. Review acquired GIS data of leak survey analysis and set up a proper localized data environment for route optimization testing.

Test Route Optimization Tools

Finalize set up of a localized environment to mimic standard leak survey procedures (based on sponsor feedback) Conduct route optimization tests on sample data and evaluate the performance. Modify route optimization settings to find the best fit for the most efficient solution. Document route optimization results and compare them to current leak survey performance times. Document all procedures necessary for project sponsors to perform the route optimization analysis internally.

Results

The team consulted the stakeholders on the current leak survey practices. The process involves printing paper gridded maps that shows locations needed to be surveyed. As the surveyor drives and surveys those areas, the areas are highlighted and marked as completed. If a leak is found, a call is placed to the leak follow up department and a tangent workflow is started. Once all the infrastructure on the map is surveyed, the surveyor returns the map and is given a new one to start. The team found that most stakeholders were not using a digital process. No current software is being used in this process and getting GIS data of the infrastructure in each survey area is proving difficult.

The team identified two potential solutions. The first provider offers a solution that uses historic traffic data and GIS point inputs from the client to route efficiently while tracking the field worker via the app on their smartphone or tablet. This option allows the field worker to take notes of survey locations in real time.

The second provider was interested in developing a custom solution but has a starting point for leak survey data routing. This provider already has a product used for follow-up leak surveys and integration of new routing leak survey would be seamless.

Status

The team is currently discussing and trying to get sample GIS or excel data from the stakeholders to test out the solutions. Having the sample data will allow us to test how the selected software would fit into current leak survey workflows, or if the addition of the software as a routing tool would disrupt the workflow by causing extensive startup costs to find and format the data into a useable format.

Additionally, the team is working with gaining access to the second technology providers platform to document any potential needed improvements or additional features.

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OTD Operations Technology Development

DOE iM4 AOI4 Cost Share

Researchers will develop a System Design Document for a Integrated Methane Monitoring Platform software solution. This will provide better information and support decisions by the scientific community, policy makers, and government agencies, and utilities.

Project Description

The scientific community, government officials, and policymakers have had an increasingly challenging problem of finding accurate data to describe the GHG emissions landscape, with methane measurements posing one of the most difficult challenges. Accounting for methane emissions is complex, requiring a variety of technologies that currently cover different spatial and temporal resolutions, are reported in different units, and at times depend on varying operating work practices. A system does not currently exist for spatially and temporally resolved methane emissions reporting, estimates, or observations.

The proposed Integrated Methane Monitoring Platform (IMMP) platform supported by the Engineering, Design, Deployment, and Operating Plan (EDDOP), would not only identify the needs of the scientific community, policy makers, and government agencies, it would also enable operators to better understand the data being collected and to demonstrate progress in reducing emissions. An integrated methane monitoring platform can provide methane emission data to the greater industry, enabling people, organizations, and communities to make informed decisions about the energy transition. This project will develop a better understanding of baseline methane emissions data and develop a system design for a software solution to this problem.

Deliverables

The main project deliverable will be a system design document.

Benefits

The IMMP will serve the needs of the scientific community, policy makers, and government agencies to better inform decisions around the state of methane emissions and the change in those emissions over time. It would also enable operators to demonstrate progress in reducing emissions.

Technical Concept & Approach

The primary tasks for this project include:

Industry Engagement

Leverage learnings from related, large-scale methane emissions projects to inform the technical panel and the IMMP EDDOP, specifically the Veritas Reconciliation Protocol and Project Astra. This project will build upon the work done in the Veritas MRS by using the standards in the integrated methane monitoring platform. Building upon a clear taxonomy and data collection system will streamline database design and reinforce consensus around the MRS framework. The MRS framework will facilitate communication and collaboration among the various stakeholders involved in this project and in future implementation, especially those inputting methane measurement data to the system.

Public Outreach and Environmental Justice

Develop a public health, environmental impact, and socio-economic survey to be distributed to community members for anonymous submission. This information will be used to identify key community concerns and needs that may be addressed through the improved quality and availability of emissions data resulting from the development of this platform.

Technical Advisory Panel

Convene a cross-domain team with its software development team and a technical advisory panel composed of national methane emission experts to meet periodically and address the methane measurement considerations required for designing a multiscale, integrated methane monitoring system. The technical advisory panel will address the following in documenting platform requirements and design: 1) Point-source, facility-level atmospheric measurements systems considerations, 2) Regional emissions estimates considerations, 3) Integration of multiscale methane emissions data, and 4) Process for determining uncertainty estimates.

Requirements Gathering

Gather all requirements around data formats, methods for aggregating data, uncertainty estimates, platform functional requirements, and other requirements as determined by the project team and technical advisory panel. This project will use industry best practices for successfully achieving operational improvements through business process changes and technology integration and deployment.

System Design

Document the system, comprised of workflow processes, procedures, and information technology components, resulting in the IMMP EDDOP, delivered as a System Design Document.

Results

The team has initially been focused on stakeholder engagement. They created draft questionnaire soliciting use cases and requirements to share with industry engagement leaders. They also developed a stakeholder analysis with an emphasis on inclusivity, particularly among disadvantaged communities and underrepresented groups, and created a comprehensive public health, environmental impact, and socio-economic survey to identify community needs and concerns.

Status

The team's next step will be to share the industry engagement questionnaire with industry leaders to gather feedback before disseminating the survey.

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Ground Cover Change Detection for Transmission Pipelines

Researchers will identify cost-effective technologies for monitoring pipelines and identifying potential threats/changes in order to automate this time-consuming task.

Project Description

Pipeline operators have requirements under regulations (e.g. § 192.614 damage prevention programs) and various company-based voluntary initiatives to monitor and inspect transmission pipelines. In some cases, these programs require daily, manual effort to ensure that there are no external threats that need to be further monitored. Fortunately, new technologies can help to automate these processes or make them more efficient.

Maintaining pipeline infrastructure requires understanding and monitoring risks to that infrastructure, especially assets that have either high likelihood or consequence of failure. This includes identifying high consequence areas (HCA), monitoring transmission assets both internally and externally, and monitoring changes in surface cover around that infrastructure and in those areas.

For some operators, monitoring this infrastructure includes driving many miles of pipe each day to inspect and detect changes or threats. While this is a necessary process, there may be improvements to this process that increase efficiency and accuracy in assessing changes to the ground cover conditions.

The primary objective of this project is to identify cost-effective technologies for monitoring pipelines and identifying potential threats/changes in order to automate this otherwise manual, time-consuming processes.

Deliverables

The deliverables from this project include lab test results, pilot test results, and a final report.

Benefits

Monitoring pipelines, especially critical infrastructure like transmission pipelines, can be time-consuming and expensive. Through the application of modern technologies and processes, there may be opportunities to improve the efficiency of this task and potentially identify threats that would otherwise go unseen. Identifying processes that simplify and improve monitoring activities will improve safety, reliability, and cost-effectiveness of our operations.

Technical Concept & Approach

The primary tasks for this project include:

Background and Product Review

Identify relevant commercially available technologies that could be used for this use case, including understanding research that has been completed for previous projects. Select technologies and identify them based on cost-effectiveness, ease of use, and other requirements as gathered from the participating sponsors.

Lab Testing

Test the selected technologies in the controlled environment of a pipe farm. Design testing to address leading concerns of the utilities, such as digging (e.g. construction, landscaping, etc.), vehicles driving or parking over the surface, change in surface material (e.g. paved over or gravel installed, etc.), and other situations indicated by sponsors. Provide the results to sponsors.

Pilot Demonstrations

Select OTD project sponsors to conduct pilot demonstrations within their service territory. Selected sponsors will be asked to share transmission pipeline datasets to assist in identifying pilot area. Results from pilot testing will be reported and presented in a webinar.

Results

The project team has conducted multiple kickoff and scoping calls with sponsors to determine research focus areas and has determined that the focus will be on:

Proximity Monitoring and Sensing

The technology selected for piloting should complement current monitoring procedures. Piloted tech will augment field monitoring capacity by deploying sensors to detect and alert staff to critical scenarios at ground level.

Remote Sensing

The team is engaged in ongoing discussions with sponsors about current uses of satellite technology for encroachment monitoring purposes, and methods or opportunities to either improve, complement, or substitute current practices with new approaches and/or technologies.

Status

The team completed a market overview research framework and identified products of best fit. Initial piloting on GTI Energy's campus will take place later this summer for two separate technologies aligned with the Proximity Monitoring and Remote Sensing use cases.

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Traceability Template for Assemblies

Researchers will create a consistent traceability framework for common assemblies. The traceability framework will include a smart tag (barcode) and a traceability record template in order to improve data quality, increase safety, and ensure regulatory compliance.

Project Description

Operators must retain traceability records of their assets for regulatory compliance and/or internal procedures. Traceability records include material properties and test reports, joining and welding reports, and pressure test records. To enable asset traceability for regulatory compliance, the industry developed and implemented ASTM F2897 for material traceability of plastic pipe and fittings and is in the process of developing similar standards for steel pipe and fittings including digital Material Test Reports. ISO 12176 provides standards for traceability of plastic joining operations. Many operators have implemented technology to capture traceability data for installed assets based on these standards.

Traceability of assemblies (such as regulator stations and pre-tested pipe) lacks standardization and records are often a manually compiled set of disparate datasets in PDF, spreadsheet, or scanned paper formats. Locusview is working with fabricators to digitize material traceability and test records. The industry would benefit from templates and standards that can be applied consistently for common assembly types.

The objective of this project is to create a consistent traceability framework for common assemblies. The traceability framework will include a smart tag (barcode) template based on GS1 standards that embeds traceability for all constituent materials for assemblies, and a traceability record template for fusion/welding procedures, OQ verification, and pressure testing, and other required datasets from the manufacturer or fabricator. The assemblies included in the scope of this project could include regulator stations, meter set assemblies, pre-tested pipe segments, mainline valves, pigging launcher/ receivers, and compressor stations.

Deliverables

The deliverables from this project include:

- A template for a digital, standardized fabrication report
- A model for universal unique IDs for assemblies
- A smart barcode template

Benefits

This project will improve data quality, increase safety, and ensure regulatory compliance. Data quality will be as a result of fabricators will providing data in a standardized format using templates. Utilities will be able to input, find, and utilize assembly traceability data because it will be standardized and machine readable with the smart barcodes and associated fabrication report. Safety will be increased because utilities will be able to perform enhanced quality assurance for assemblies including material, fusion/ weld, and OQ verification. Utilities will be able to prove compliance with regulatory requirements with standardized fabrication reports for assemblies.

Technical Concept & Approach

The primary tasks for this project include:

Assembly Selection and Work Group

Select up to three assembly types and form technical work groups for each. The work groups will include representatives from manufacturers and fabricators.

Traceability Framework

Create a framework for the assembly traceability records for each of the selected assets. The framework will include a data model template for fabrication reports for the required traceability elements for each assembly type including materials, fusion/weld, pressure test and any other relevant traceability data. The deliverable will be a data model template that manufacturers and fabricators can populate with data for delivery to their utility customers.

Smart Tag Template

Create a template for the smart tags that will be applied to the physical assembly. The template will be based on GS1 standards and will include universal unique IDs for the assembly that encompasses material traceability for all subcomponents, required attribute data (material attributes, ratings, manufacturer, fabricator), and links to supporting datasets defined in the traceability framework (test reports, certificates of compliance, fusion/weld record, pressure test, OQ verification, pictures)

Results/Status

The project team created a draft data model for regulator station assemblies that includes a cover sheet, bill of materials, engineering drawing, hydrostatic pressure test records, weld maps, and MTR/COCs. The data model is being reviewed by utilities and service providers. Once the data model is finalized, a pilot project will be conducted with a regulator station service provider.

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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.

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Reserve Strain Capacity Determination

Researchers are working to develop and demonstrate an information fusion network which captures the interacting threats that act on high-strength steel transmission pipelines in order to better understand the risks resulting from ground movement.

Project Description

The goal of this project is to develop and demonstrate an information fusion network which captures interacting threats that act on high-strength steel transmission pipelines where strain-based design principles are employed. The information fusion network will incorporate satellite-based ground movement data, infield strain measurements, pipe/soil interaction models, strain accumulation models, detailed metallurgical information on the behavior of the pipeline steel and girth welds, damage propagation in the steel under interacting threats, and knowledge of the past and anticipated loading envelop of the pipeline.

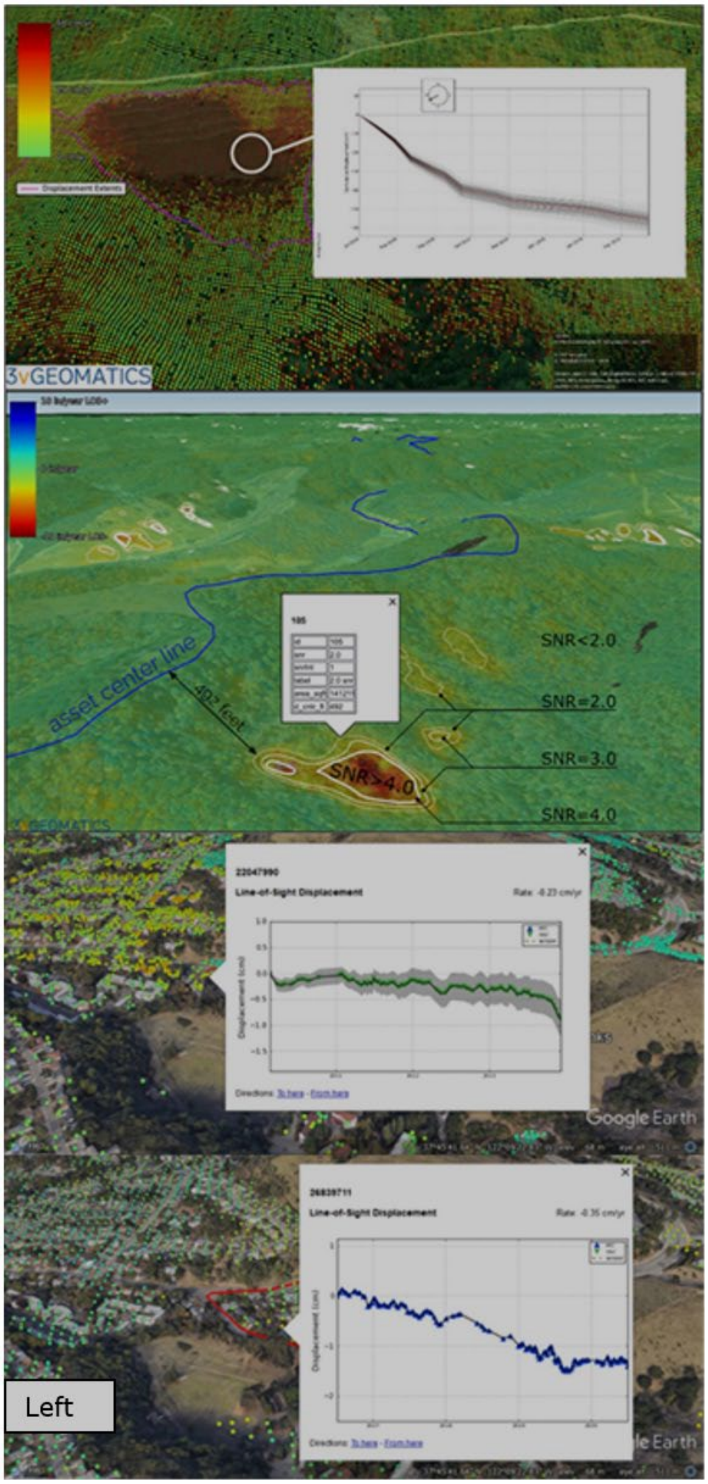
The output of the incorporated models will be twofold: accumulated strain estimates with uncertainty defined, and reserve strain capacity of the pipeline with uncertainty defined. Decision nodes in the network will allow scenario analysis for identifying suitable interventions to address reserve strain capacity of the pipelines of interest.

Deliverables

The deliverables from this project include a final report, a framework and tools for converting satellite measurements to pipeline strain, and a report providing a 5-year historic review of ground movement measured satellite data for the corridors of interest including inspection reports from that timeframe

Benefits

The objective is to develop a model to measure accumulated strain on existing pipelines, specifically those that may result from ground movement. Strain -level data on pipeline infrastructure is important to understand how damage incurred by plastic deformation impacts pipelines and pipeline risk. With existing pipelines, the accumulated strain over time is unknown, which means there is no baseline to measure strain data. Not having this strain measured over the pipeline's operational life can create a challenge for the pipeline industry, calling for a need for both tools and models.



Technical Concept & Approach

The project team will conduct satellite measurements and Dimensional Image Correlation (DIC) measurements. The team will use satellite measurements, DIC measurements and any other available strain measurements to develop a framework for interpreting satellite ground movement data and converting to pipeline strain.

Results/Status

The team completed developing the information fusion network that addresses both strain demand, and strain capacity. The current focus is on writing the draft final report, which will be submitted to the technical advisory panel for review in July. The final report will be submitted to US DOT PHMSA in September.

Three peer reviewed papers describing aspects of the project work have been accepted for presentation at ASME conferences focused on pipeline design and performance.

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