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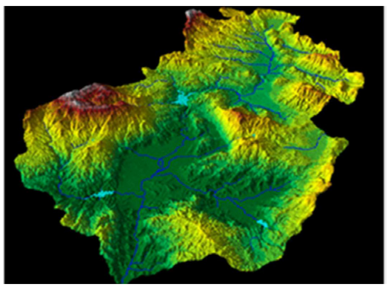
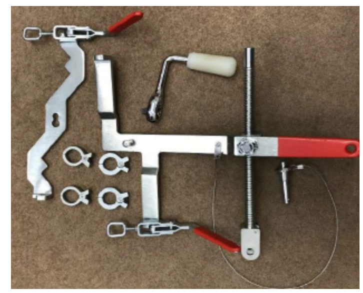
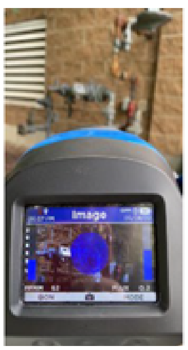
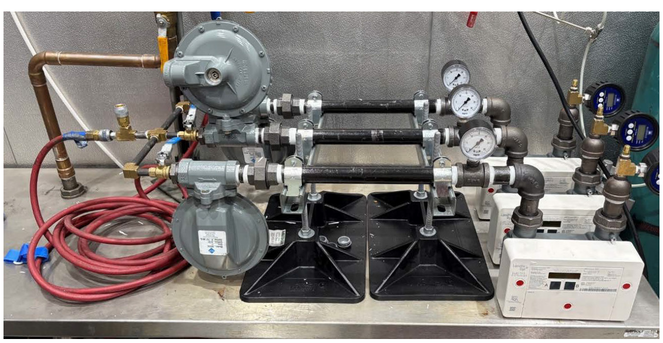
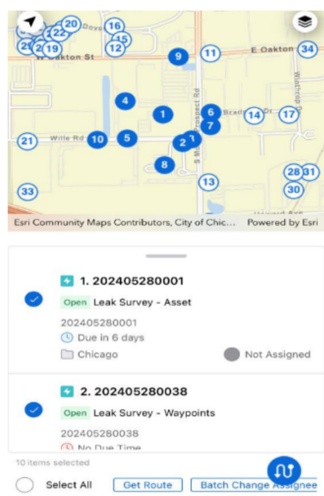


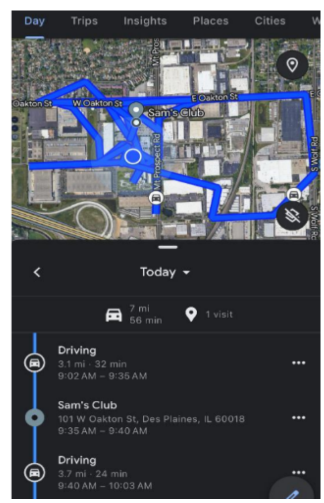
RESEARCH PROJECT SUMMARIES 2024

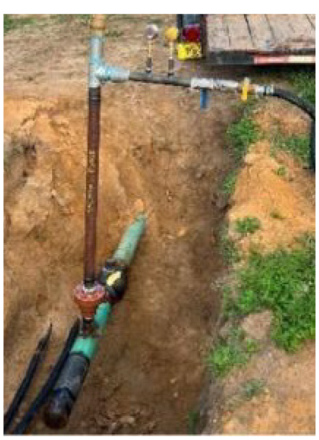


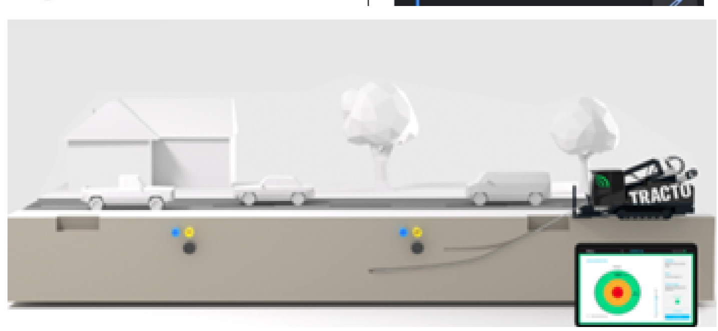












Operations Technology Development, NFP

RESEARCH PROJECT SUMMARIES

2024

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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 31 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. In 2024, our research & development efforts have been guided by a clear vision: to drive innovation that strengthens safety, enhances operational efficiency, embraces the evolving energy landscape, and unlocks the transformative potential of artificial intelligence.

Across all projects, we remain committed to advancing solutions that not only meet today's challenges but anticipate tomorrow's opportunities. A core part of this work has been fostering a collaborative environment that encourages open sharing of challenges and collective problem solving. By working together, we've been able to surface insights faster, identify practical solutions, and embed learnings more effectively into our operations.

Our initiatives spanned a wide spectrum, from reinforcing safety across operational activities and streamlining processes, to deepening our understanding of renewable integration, and deploying artificial intelligence (AI) to enhance monitoring, forecasting, and decision making. Each effort reflects OTD's belief that innovation is strongest when it is shared and that progress is a product of both technical advancement and continuous learning.

This report provides summaries of more than 100 projects worked on in 2024 within OTD's program and includes an overview of several of OTD's most significant achievements. Example of these projects include evaluating technologies that can help prevent damages during cross bore activities, minimizing the time and the amount of gas released to the atmosphere during venting, and using AI as well as satellite imagery to help operators better understand changes in right or way and their assets. All of these projects are core to the industry's success in delivering a safe, reliable, affordable, and environmentally conscious energy solution.

OTD Members

- Ameren Illinois
- APGA Research Foundation
- Atmos Energy Corporation
- Avista Utilities
- Blackhills Energy
- Consolidated Edison Co. of NY, Inc./ Orange & Rockland Utilities, Inc.
- Central Hudson (joined 2025)
- Duke Energy Corporation / Piedmont Natural Gas Company, Inc.
- Enbridge Gas Distribution Inc./Enbridge NC/ Enbridge Utah
- Exelon
- GDRF
- Intermountain Gas Company
- Liberty Utilities
- Louisiana RDC
  - Atmos Energy Corporation
  - CenterPoint Energy, Inc.
  - Entergy Corporation
- National Fuel Gas Distribution Corporation
- National Grid
- New York State Electric & Gas Corp. / Rochester Gas and Electric
- Nicor Gas
- NiSource Inc.
- NW Natural
- Oklahoma Natural Gas
- Pacific Gas and Electric Company
- Peoples Gas
- Southern California Gas Co., a Sempra Energy Utility
- Southwest Gas Corporation
- Spire (Alabama)
- TECO Peoples Gas
- UGI (joined 2025)
- Washington Gas

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

Chair of the Board

Hart Gilchrest

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, auto-mating the process of documenting surveys and leak locations.

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

Pipeline Purging Program Update

Bradley Bean

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

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

Synergi Pipeline Simulator

DNV GL

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

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

Lift Assists for Pavement Breakers and Rock Drills

Integrated Tool Solutions, LLC

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

Contact: Ryan Purczynski
951-929-4808
rpurczynski@integratedtoolsolu-tions.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

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

Informational Products

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.

Selected OTD-Developed Technical Reports

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)

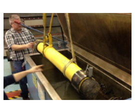
PIPE MATERIALS, REPAIR & REHABILITATION

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

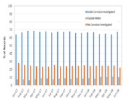
A Final Report is available on research into field-applied polyurea coatings for gas industry use. Through a new initiative, long-term field trials will be conducted to evaluate these additional coatings and determine a cost-effective coating-application method and process.

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.

Spray On leak seals for Meter Set Assemblies (MSAs)

Researchers evaluated spray-on, brush-on, or wrap-type solutions to seal thread leaks on MSAs, and most recently evaluate the LLFA tape's ability to repair active leaks on threaded pipe fittings at a working pressure of 60 psig.



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.

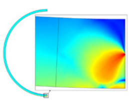
Cold-Patch Products Performance Results

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

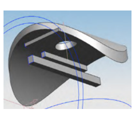


Correlating Pipeline Operations to Potential Crack Initiation, Growth, and Arrest

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.

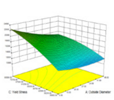
Hydro-Testing Alternative Program

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).



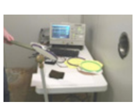
Leak-Rupture Boundary Report and Calculator

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

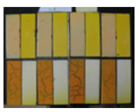
Extensive research and testing culminated in the release of a report that provides valuable information on the properties and performance of various tracer-wire products for use in horizontal directional drilling (HDD) operations. (OTD-13/0001)

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.

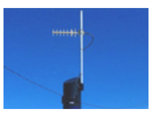
Assessment of Vehicle-Barrier Design for Aboveground Facility Protection

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.

Training First Responders

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.

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METHANE EMISSIONS/DETECTION & GAS QUALITY

INTELLIGENT UTILITIES

RISK & DECISIONANALYSIS MODELS

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.

OTD Operations Technology Development

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

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-assessment efforts.

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

Results

The project team employed multiple approaches to assess the current ECDA environment, capture sponsor needs, and analyze areas of strength as well as performance enhancement opportunities. A robust ECDA literature review was performed resulting in the write-up of fifty-three (53) standards and peer review papers related to direct assessment, primarily to external corrosion direct assessment. Included in each write-up was a brief summary of the key points or objectives and a bullet list describing how the particular standard or paper could support ECDA enhancement. Additionally, a thirty-six (36) question survey regarding current ECDA practices, limitations, and requirements was distributed to the OTD sponsors for the project. The literature search and survey results were combined and an ECDA analysis that was conducted. From the literature search, survey results, and ECDA analysis, potential opportunities to enhance current ECDA practices was generated. The opportunities were broken up into seven categories, including 1) Data and Preassessment, 2) Inspection Tools, 3) Training, 4) Casings, Facilities/Stations, and Pavement, 5) Failure Analysis; Corrosion Rates; and Tracking, Trending, and Effectiveness, 6) Risk-Based and Probabilistic Analysis, and 7) Accelerate and Simplify.


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

This project is complete and a Final Report has been issued to 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.

Cybersecurity Working Group

This project established and facilitated 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 was to establish and facilitate a focused working group in order to build a strategy to help operators mitigate cyber threats aimed at critical energy-industry infrastructure. Through execution of an initial workshop, the team identified 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 included 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. 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 identified potential integrated solutions providing real-time situational awareness of the natural gas operating environments.

Technical Concept & Approach

Specific tasks in this project include:

Cybersecurity Workshop

The team hosted working group meetings with utilities on cybersecurity which established a baseline of technical information, described the present-state of the security solution landscape, and identified where additional research may be required.

Cybersecurity Roadmap and Content Repository

The team developed a strategy for helping mitigate cyber-threats based on workshop results and feedback from operators. Priorities for addressing natural gas infrastructure cybersecurity fell 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 took into consideration the large number of stakeholders who played a role in mitigating cyber-attacks and the unique and innovative ways they needed to be engaged. The team upgraded the present web-based cybersecurity repository to house information on new studies, projects, reports, conference proceedings, and more that were made available to members.

Results/Status

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. Research focus areas and priorities were defined, discussed, and agreed upon. From these activities, a list of potential research opportunities that project sponsors could consider pursuing as OTD-funded projects has been developed. The concepts have been organized around the following seven categories that were discussed early in project execution: Best Practices, Physical Security, Software/Monitoring, Situational Awareness, Policy/Regulatory, Training, and Industry Outreach.

This project is complete and a Final Report has been shared with OTD members. Recommended future phase efforts include working with sponsors to leverage the list developed under this project to identify research priorities for future proposals for OTD projects.

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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 due to cross-threading, overtightening, and improper O-ring installation.

Project Description

This project aims to improve the performance and integrity of tapping tee caps used in gas distribution systems by collaborating with fitting manufacturers to develop innovative alternative designs. The effort focuses on identifying manufacturers with the capability to enhance cap features, particularly leak-tightness and mechanical reliability, and engaging them through a structured Request for Proposals (RFP) process. Through industry collaboration, proposal evaluations, and sponsor engagement, the project will ultimately support the development and potential deployment of advanced cap solutions, contributing to safer and more efficient gas infrastructure operations.

Deliverables

The deliverables for this project include identifying fitting manufacturers capable of developing improved tapping caps, creating and distributing a Request for Proposals (RFP) to solicit innovative cap designs with enhanced leak-tight and mechanical performance, and engaging selected manufacturers through follow-up meetings to evaluate their proposals. Additionally, the project will deliver a sponsor webinar to present progress and gather feedback, and conclude with a comprehensive final report summarizing all activities, findings, and recommendations.

Benefits

Polyethylene Service Tee "nuisance leaks" are a major concern for the LDCs as they can be expensive to fix, because they usually require costly excavations. Creating an alternative cap that is more reliable than the current threaded caps, such as a fusible-type cap, could save LDCs money and time because of the reduced amount of "nuisance leaks".

Technical Concept & Approach

Specific tasks in this project include:

Identify Fitting Manufacturers

Work with various tapping tee manufacturers to determine interest in developing alternative caps for their tapping tees and share sponsor requirements with the participating manufacturers.

Go / No-Go

A go/no-go decision will be made based on the technical viability of the concepts and the ability to identify a manufacturing partner. A fitting manufacturer will be chosen to develop an alternative cap.

Possible Follow-up Actions

Based on interest and needs of the fitting manufacturers, follow on efforts may be required. The project team and project sponsors will work with the participating manufacturer(s) and develop the necessary follow-on project to develop the new tapping tee(s) / alternative caps.

Results/Status

The project team reviewed sponsors needs based on survey responses, focusing on improving capping systems to reduce leaks in service and high-volume tapping tees. Key points included reliance on mechanical seals, potential for internal seals, and reducing emissions and nuisance leaks. Suggestions involved redesigning cutters (or secondary plugs) to include a primary seal and exploring fused cap alternatives with manufacturers. Emphasis was placed on collaborating with manufacturers to develop practical solutions and reduce costs associated with leaks and re-excavation, along with the need for development funding and potential cost-sharing.

Next steps include approaching fitting manufacturers to discuss proposed designs and obtaining previous feedback or proposals from manufacturers on similar solutions.

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REMS Phase 3: Development of field Ready Prototype

The objective of this project was to develop a shutoff prototype system for isolating 20" diameter low pressure mains via 2" PE service line access.

Project Description

The goal of this project is to build on the lessons learned from the prototypes developed and tested for the previous phases of OTD project 5.16.d and develop a field-ready prototype system that can successfully deploy a custom 20" inflatable stopper into a 20" main through 2" PE service line pipe consisting of a full port ball valve, an electrofusion fitting, and a street tee fitting. This configuration was decided upon based on results found during the previous phase.

Deliverables

Deliverables for this project included a lab-tested prototype, a field-ready, sponsor-approved, procedure for field crews to follow, and a final report.

Benefits

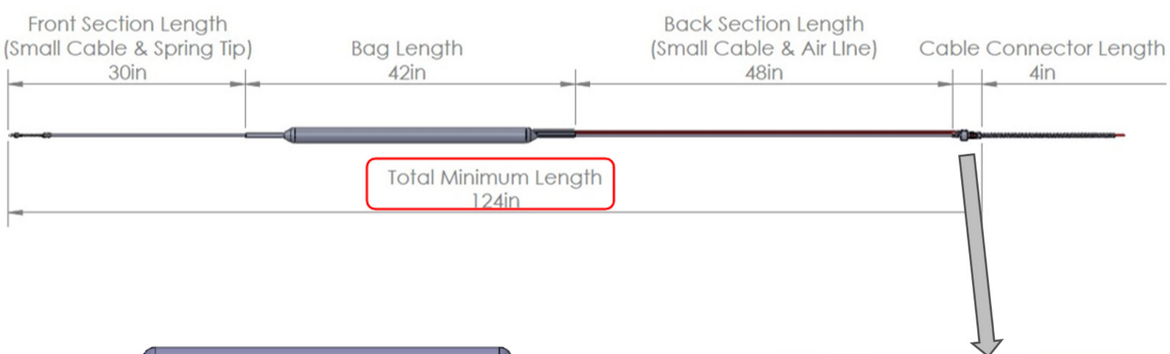
Large diameter low pressure mains typically do not have shutoff valves installed which can be used to isolate sections of main. During emergency incidents local distribution companies are often tasked to expose, tap, and install inflatable stoppers on either side of a leaking main to isolate the flow of gas. These activities can be lengthy and costly. The ability to isolate large diameter mains without needing to excavate will save time, reduce cost, reduce facility damage risk, reduce worker injury risk, and will reduce negative impacts to customers.

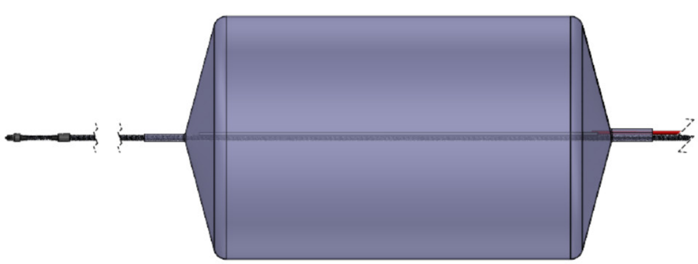
Technical Concept & Approach

Specific tasks in this project include:

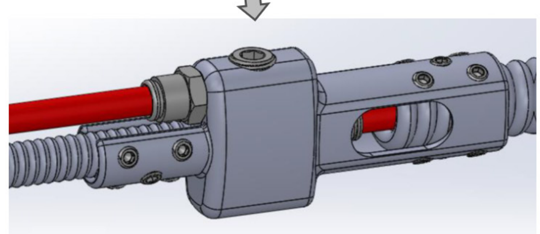
Product Enhancements

The work in this task includes further development and enhancement of the prototype system from Phase 2. The team will construct multiple enhanced inflatable balloon stoppers (addressing known issues from Phase 2) and assemble the entire prototype with the calculated length segments. Additionally, the team will make a new stuffing box with service line seal and develop a nitrogen inflation system (with gauges).

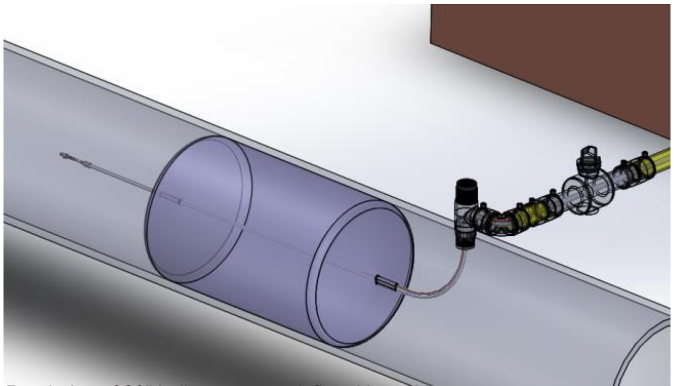




Inflated balloon stopper



Cable connector



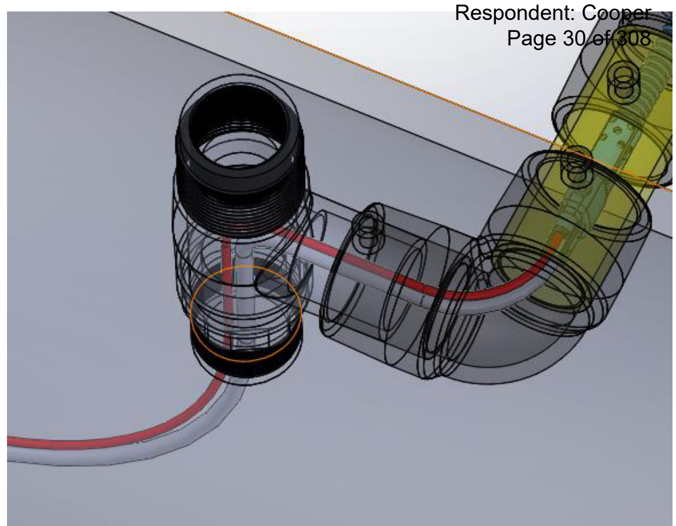
Rendering of 20" balloon stopper inflated in main

Product Testing in Lab

The work in this task includes testing and refining the prototype system and procedure by deploying the revamped Phase 2 inflatable balloon stopper to validate the minimum required length, identify the proper range of service lengths, evaluate how to determine when the balloon stopper is sufficiently in the main without seeing inside the service or main, and determine the number of cable unwraps which are required pre-inflation to prepare the balloon stopper for inflation. Additionally, an inflation procedure with nitrogen will be developed to investigate how much pressure to use, determine how long the process takes, and see how pressure gauges can be implemented. A removal process will also be developed to be able to deflate and retrieve the stopper from the main. Lastly, the team will identify and/or select live gas camera systems to be used before deployment and test the use of these systems on the specified service line configuration.

Procedure Writing (Go/No-Go step)

With approval to move forward from project sponsors based on previous results, this task includes developing documented field procedures for deploying the system; with assistance, input, and review from the project sponsors.



Cable connector and feed line, fed thru service line

Results/Status

This project was kicked off in Q3. The project team reestablished communication with the bag manufacturer and began discussing the desired design enhancements to the 20" REMS Phase 2 Inflation Bag which were identified during the previous phase of the project. The 20" REMS Phase 3 Inflation Bag design is expected to be finalized early in 2025, and the bag manufacturer will develop the bag prototypes for testing.

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OTD Operations Technology Development

ORFEUS Obstacle Detection for Horizontal Directional Drilling

Researchers developed 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 was 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 was 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, the 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. During the current Phase of the project, various field evaluations will be continued with the enhanced ORFEUS system to demonstrate continual successful operations.

Deliverables

The deliverables for this project included improvements to the bore-head radar, software, and user interface, 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 the general public, utility companies, and their pipeline contractors. This technology can also enhance the installation 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 to require further effort to produce a commercially viable product.

Communications Links

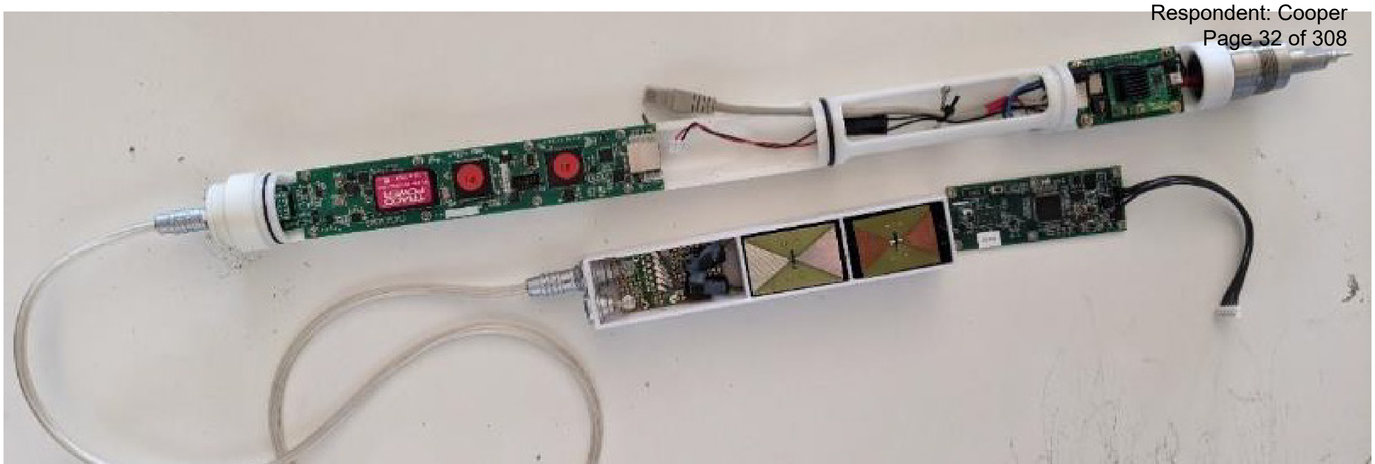
Improvements to the modem and power modules, both in the cab and at the drill head based upon the existing design and digital signal processor architecture enhanced by using information gained from the previous project's field trials.

System Software

Development of the software for the HDD radar system. Data analysis from field demonstrations of the previous system successfully proved the capability of target recognition in different soil conditions; however, 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.



The mockup of the system including radar board, angular sensor, and side antenna without cover (top view)

Operational Tests

Operational demonstration trials to confirm the operational reliability and readiness of the system at various sites and soil conditions.

Results/Status

Initially, a field trial of the ORFEUS system was conducted in 2017 on a purposely built testing area including several targets (buried 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 set of antennas constrained 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. The main innovation introduced in the design concerns the splitting of the transmitter/receiver electronics into two parts connected with a large bandwidth and shielded cable.

Testing was executed first with a medium-frequency GPR antenna in order to evaluate the dynamic range. Then, the electronics were mounted on a high-frequency GPR antenna whose electromagnetic characteristics are similar to the ORFEUS front antenna.

The first operational systems trials were carried out in Lennestadt, Germany. The completed hardware and software were installed on an HDD drill rig. The aim of the test was to evaluate the integration of the entire system. Testing was conducted on the enhanced ORFEUS 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. With this completed, 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.

The ORFEUS system was subjected to various test phases during and after the actual development to test the performance and reliability. While certain components such as the side antenna, display, drill head and drill rods as well as the data transmission and power supply can be assumed to have reached TRL 9, the front antenna was not functioning satisfactorily to meet the development teams goals.

The company commercializing the ORFEUS system, and the technical consortium involved, are confident that this is a solvable issue and that the product will change the HDD industry and be a success. Further work will be carried out after the end of this project to reach a stable TRL 9. The ORFEUS system was publicly debuted at the BAUMA construction trade fair in April 2025.

The final report on ORFEUS Obstacle Detection for Horizontal Directional Drilling - Improved Tools to Locate Buried Pipe in Congested Undergrounds was completed and released to OTD members in June 2024.

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OTD Operations Technology Development

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

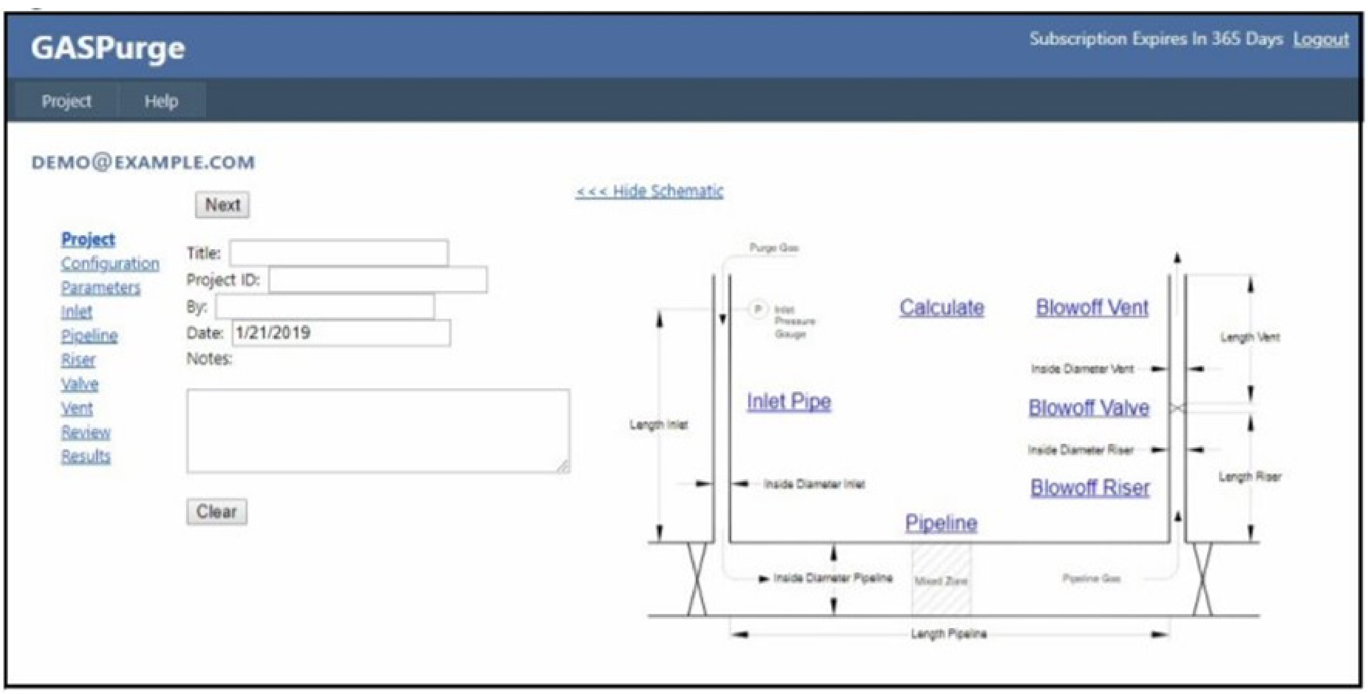
The objective of this project was to develop a pipeline purging software program to enable users to quantify methane emissions consistently and accurately.

Project Description

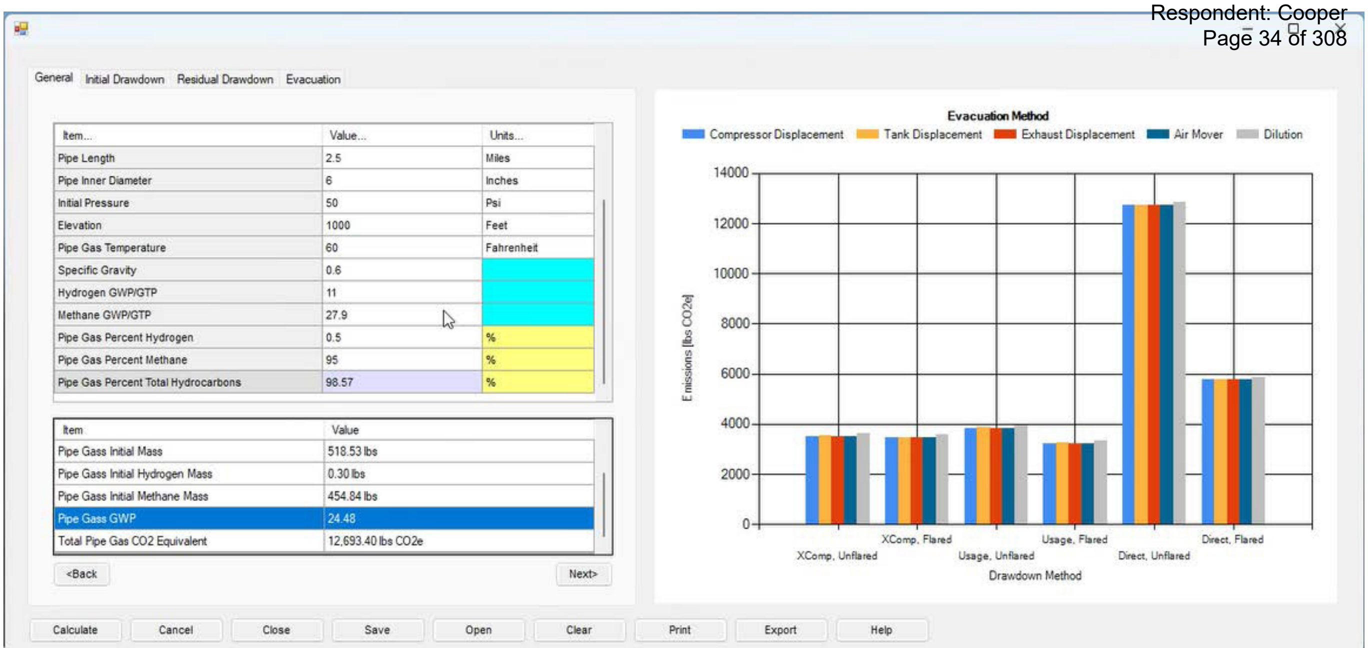
The main driver for this project was the need to create an improvement on an existing software program to allow users to easily calculate methane emissions savings from using various types of purging alternative processes and equipment (i.e., cross compression) and hydrogen blending operations. The project team collaborated with a software developer to enhance the purging software to calculate the emissions savings when using the methane savings alternative practices and equipment. The intent was to support operators in determining the optimal strategy for emissions savings by considering various factors, such as: Gas composition; Equipment type; Transportation distance; Emissions savings methods for both methane and carbon; Feasibility breakeven analysis for emissions footprint. All the emissions (flaring, diesel combustion from compressors, and emissions from the transportation of equipment) were quantified separately in the software and their Global Warming Potential (GWP) was reported as well.

Deliverables

Deliverables for this project included development of the required algorithms and calculations required to produce the listed results, a revision of the existing software to accommodate the new data inputs and presentation of the results, along with the associated supporting documentation and a report detailing the results. Rather than modifying the original GasPurge software, a separate software was instead developed to accompany the original for this specific industry need.



Current GASPurgeTM interface that will be updated with this project.



Natural gas volume calculation performed using user inputs for the pipeline section being purged or cleared.

Benefits

Accurately capturing savings in the volume of gas loss during purging operations helps operators make better financial decisions about which emission reduction work to fund. This software supplies operators with the calculations for emissions savings needed for reporting to state and federal governments or corporate environmental, social, and governance (ESG).

Technical Concept & Approach

Specific tasks in this project involved software development which included creating new calculation algorithms, a new user interface, and the installation and setup of the software. The team conducted in-house validation of the calculations, functionality, and user interface; distributed beta version of software to Project Sponsors for input and feedback and facilitated a live demonstration; and completed and distributed the production version of the software at the conclusion of the project.

Results/Status

The project team met throughout the software development process to discuss the software's functionality and assess its usefulness for operators. One important feature of the software is the ability to export all calculations in the form of an Excel spreadsheet for easier recordkeeping. This allows all purging jobs to be saved and documented, which helps operators to keep track of their avoided methane emissions in terms of carbon equivalents.

In general practice, the calculation begins by accounting for the natural gas present in a pipeline that is to be purged or cleared. This volume of natural gas is calculated using the pipeline's length, diameter, and operating pressure. This volume of gas is counted as avoided emissions, since the operator is instead using a purging alternative to venting to the atmosphere. Since the EPA has characterized the Global Warming Potential for various types of emissions, the software uses units of carbon equivalencies, or lbs. CO2e, to represent all of these emissions in common units for comparison. A more detailed description of the methods used for emission calculation can be found in the final report.

A project update to review the Beta version of the software and feedback on the Beta version was requested by OTD members. The project team worked with sponsors to obtain feedback to integrate into the final version of the software. A User Manual that is accessible from the software will be provided to users, and ongoing support and maintenance of the software will be provided.

The final report of Modify Pipeline Purging Program for Calculations of Methane Emissions Savings, Including Hydrogen Blends was completed and released to OTD members in March 2025.

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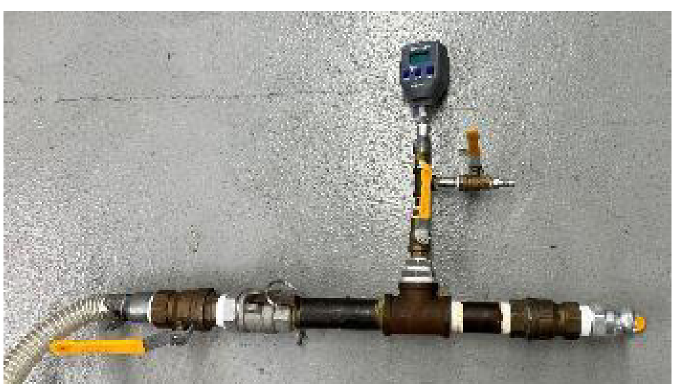
Purging Gas Pipes into Service without Venting Gas to Atmosphere

The objective of this project is to enhance and demonstrate the patented vacuum purging technology to a state of commercial readiness. This solution will eliminate or drastically reduce natural gas emissions during purging operations.

Project Description

Gas purging occurs on a routine basis in the natural gas industry. 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 serious incidents and/or outages. A vacuum purging methodology was developed in Phase 1, patented (US Patent 11,821,564) and further enhanced and demonstrated in the field during this current Phase 2 of the project. Vacuum purging is a purging alternative to avoid methane emissions related to purging pipelines into service. This method can be used to energize new or recommissioned pipelines by means of a vacuum pump, in order to avoid methane emissions into the atmosphere and minimize the risk of gas and air mixture in the energized pipes. The team continues to demonstrate the system to OTD members through live field pilots to gain necessary feedback and ultimate acceptance to bring the vacuum purging method identified in phase one to a state of commercial readiness.



Connection Kit between Vacuum Pump and Pipe

Deliverables

This project will provide the project sponsors with a comprehensive report that describes the vacuum system components and operation. This includes: Equipment that the vacuum system will need to safely and seamlessly operate “off-the-shelf”; Development and integration of a methane monitoring system to enhance safety while pulling vacuum to commission gas distribution pipe; Field demonstration of the enhanced vacuum system; and a manual that pertains to using the vacuum system for regular day-to-day operations.

Benefits

Minimizing or eliminating the current practice of venting natural gas to the atmosphere during purging can help reduce methane emissions and avoid the social impact of venting gas in an urban area and creating a public nuisance and potentially hazardous environment. By bringing the vacuum purge technology to a state of commercial offering, gas operators will be equipped with a new technology that can help reduce natural gas emissions and benefit from various programs (e.g. PIPES Act 2020, certain states have cap and trade regulations that require continued reduction in their amount of methane emissions per year.)

The vaccum purge system was attached to the new section of steel pipe - attached to the purge stack - and a vaccum was created in the new pipe down to approximately 14.5 psig

Technical Concept & Approach

Specific tasks in this project include:

Component Enhancement

The team will acquire and test all components needed so that a gas distribution company can seamlessly and safely operate the vacuum system.

Perform Field Demonstration

Once the field-ready version of the vacuum system has been configured, the team will work with project sponsors to conduct live demonstrations at utility sponsored sites. These demonstrations aim to refine any operational and component issues as well as introduce the technology to the project stakeholders.

Develop user instructions

The project team, with collaboration and input from technology component developers and sponsor feedback, will provide a user's manual for the system's safe operation and use.

Results

During this past year, the project team clarified existing procedures for best practices with subject matter experts that provided more notes to the existing procedure and elucidated the amount of acceptable air to be allowed in a pipeline.

The team demonstrated the vacuum purging system at several field sites. Field pilot demonstrations were conducted with various OTD sponsors. These sites included various new PE pipe installations. One site included 8000' of 4" PE pipe to extend the natural gas system to serve new customers. Another included a combination of 2" and 4" PE pipe in a new residential development. One even included purging into service 4500' of new pipe pipe to replace existing bare steel pipe. This installation also included 23 pre-tapped service lines. One installation in Florida was on a new steel transmission pipe; the first ever steel pipe purging operation – approximately 3.5 miles of 4" steel pipe was purged into service using the vacuum purging system. These operations were successful with almost no natural gas vented to the atmosphere during the purging operations.

In addition, a demonstration was held during a recent OTD meeting. While these demonstrations proved the effectiveness and ability of the vacuum purging system to be an effective alternative to traditional purging operations, further field demonstrations are continuing to help support industry implementation as well as support to continue to work to secure a commercializer for the vacuum purging system.

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OTD Operations Technology Development

Ultrasonic Meter Testing - Pietro Fiorentini meters

The objective of this project is to conduct evaluations of recently introduced Pietro Fiorentini Ultrasonic residential gas meter for utility and State Commission acceptance.

Project Description

This project will evaluate the accuracy of the meter metrology, long-term performance, compliance with meter standards, and smart shut-off capabilities. This effort will help the Pietro Fiorentini Ultrasonic residential gas meter become available for the US Market.

Deliverables

Deliverables for this project include an interim report detailing the short-term metrology testing results of the Pietro Fiorentini ultrasonic residential gas meter, and a final report detailing the comparison between residential gas meters from three other manufacturers for both short term and long-term metrology, as well as smart safety feature effectiveness.

Benefits

These gas meters are more compact than previous gas meters, which is desired by multiple LDC's . Additionally, these smart meters provide smart safety features such as remote shut-off, automatic shut-off at predetermined levels for various sensors, pressure monitoring, system diagnostics and remote reading capabilities.

Technical Concept & Approach

Specific tasks in this project included:

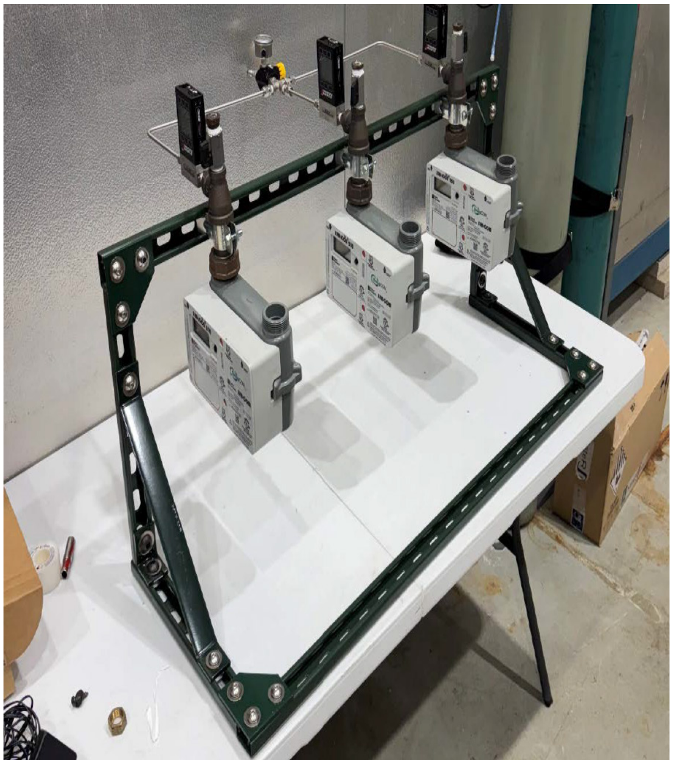
Metrology Testing

The work in this task includes both short-term and long-term metrology testing as established in OTD 5.19.h and OTD 5.20.e. The long-term metrology test will be conducted for 6 months on an outdoor test rig to evaluate these meters under summer and winter weather conditions. Additional tests will evaluate the accuracy of the ultrasonic sensors at extreme temperatures, humidity and with impurities.

Smart Meter Testing

The work in this task will include conducting multiple tests on the effectiveness of the shut-off valve and other integrated safety features. These tests will be performed at various pressure and flow rates to evaluate the performance of the shut-off at these conditions. Additionally, testing will be performed to evaluate the range/performance of the communication of these new meters.

Pietro Fiorentini Ultrasonic Flow Meter



Shut-off Valve Leak Rig (outside of Temperature Chamber)

Results

The 9 Pietro Fiorentini SSM iCON 250 ultrasonic meters were received, and all 9 meters passed both the initial accuracy and meter capacity test. Progress has been made towards completing the remaining basic and specialty metrology testing on the Pietro Fiorentini SSM iCON 250 ultrasonic residential gas meter. Three of these meters passed the Pilot Flow Accuracy Test and began the six-month Outdoor Accelerated Life Test which is scheduled to be completed at the end of Q1 2025.

Additionally, two other Pietro Fiorentini SSM iCON 250 meters passed the Resistance to Water Vapor Test (Relative Humidity). Lastly, the team also performed the Shut-off Valve Leak Test on three other Pietro Fiorentini SSM iCON 250 ultrasonic residential gas meters, which all three passed.

In 2024, the project team has completed 6 of the 16 tests, and have started three other tests. These three tests and the remaining seven tests which have not yet been started, are expected to be completed on the Pietro Fiorentini SSM iCON 250 ultrasonic residential gas meters in early Q2 2025.

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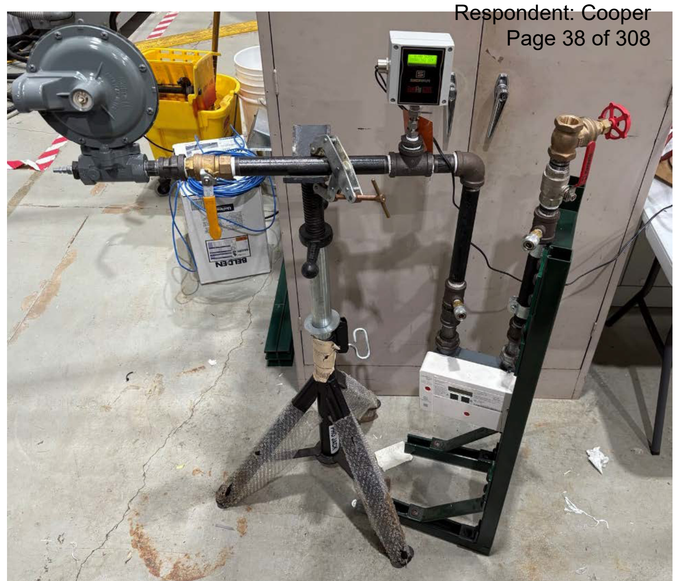
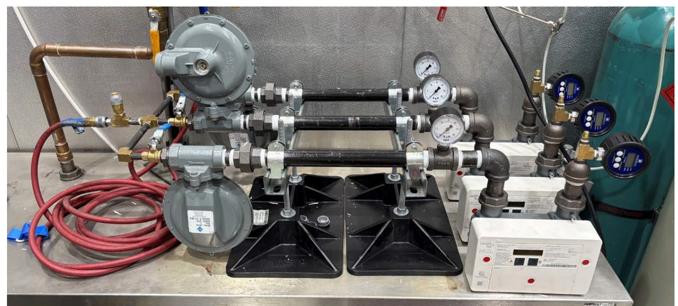


Meter Capacity Test Rig



Pilot Flow Accuracy Test Rig

Outdoor Accelerated Life Test Rig

Humidity Test Rig

Wet Spoil Remediation

Hydroexcavation used in utility work generates a slurry (wet spoil) that is problematic for disposal. This project demonstrated a wet spoil remediation technology to observe the advantages and disadvantages compared with current approaches.

Project Description

The goal of this project was to demonstrate a technology for wet spoil processing that could be readily deployed near a utility construction area. Modeled after drilling mud processing technology, the system separates soil and rock with screening, adding polymer to facilitate removal of finer soil particles with a centrifuge. This approach can facilitate the beneficial reuse of recovered solids as fill and centrate water for hydroexcavation operations. The unit could accept wet spoil from multiple construction sites and process the slurry for reuse or more efficient disposal options.

Deliverables

Deliverables for this project included a report detailing the results of a month-long demonstration pilot performed by Waste Management (WM) with a nearby utility providing the slurry. The report provided an economic analysis as well as an overview of the efficacy of this wet spoil processing system.

Benefits

Hydroexcavation and horizontal directional drilling (HDD) are common practices used in the construction and infrastructure industry. Wet spoil is a byproduct of these practices and can prove difficult and costly to manage and dispose of. Wet waste is prohibited from disposal in landfills, which means the material is sometimes hauled great distances for special disposal. Processing is meant to separate the solids from water, to reuse in construction operations or provide better disposal options at reduced transportation costs.

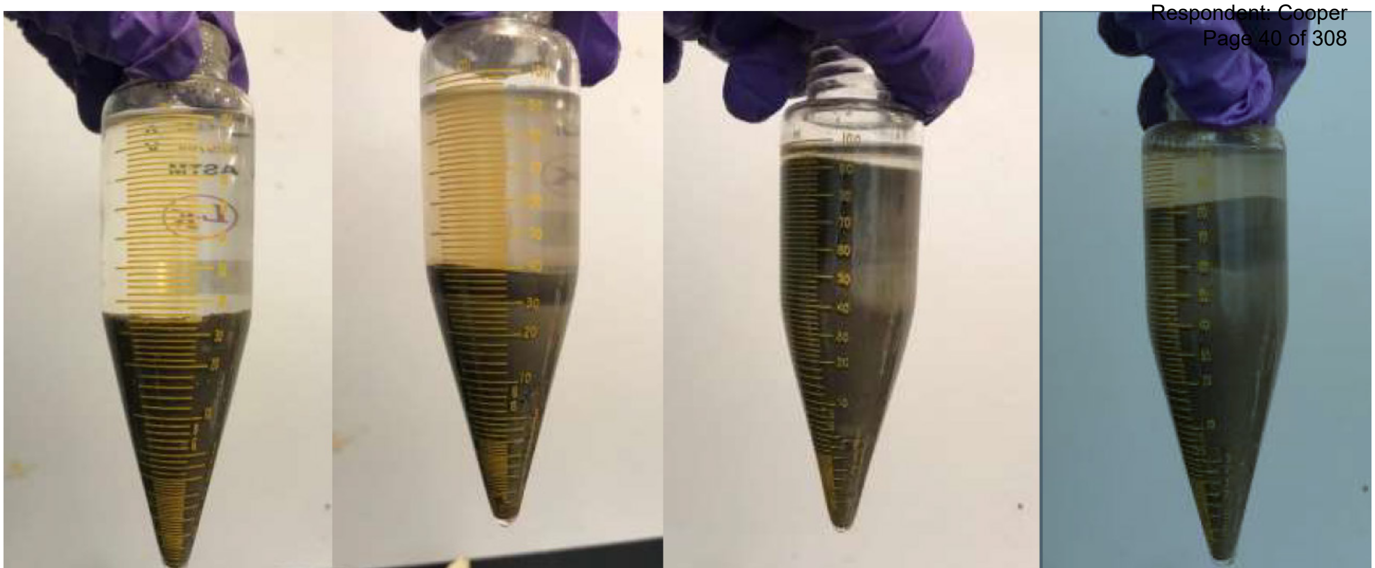
Technical Concept & Approach

Specific tasks in this project included:

Pilot Demonstration

Worked with Waste Management to set up a temporary wet spoil processing unit for demonstration in the Chicago area. Sponsors were invited to attend the demonstration.

Dolphin Services CS 18-3 Two-Phase Decanter Centrifuge



Bench-Scale Spin-out Images of tests with 70/30 Solid/Liquid, 80/20 Solid/Liquid, 92/8 Solid/Liquid, and 80/20 Solid/Liquid (Left to Right).

Pilot Analysis

Data collected during the pilot was examined, highlighting the throughput, effectiveness of the technology, and volumes of soil and water produced. A techno-economic analysis (TEA) was created to demonstrate the economic impact of this technology by extrapolating pilot costs to longer-term scenarios.

Results/Status

Data from the pilot project indicated that in a more realistic operational context costs are potentially lower compared to traditional special waste disposal methods. Two scenarios were developed to analyze cost effectiveness: a seasonal operation duration of 6 months and a longer-term facility of 2 years.In either case, a longer-term facility must operate at or near capacity (20,000 gallons daily input) for cost-effectiveness, so an adequate supply of incoming slurry is essential.

As with many other endeavors, location and site selection are critical factors to consider. Specifically, disposal requirements and costs can vary with state or local regulations governing disposal of hydroexcavation slurry and the reuse of recovered water and solids. The proximity to a landfill or other disposal facility and a water treatment plant will influence the transportation costs.

To illustrate the impact of water recycling, a unit cost was determined for only process-related costs, which include mobilization/demobilization, equipment, personnel, and polymer. In a more favorable scenario, a longer-term facility would use grid power rather than a rented generator. About 75% of the recovered water is either recycled in the process or taken by hydroexcavation trucks, avoiding much of the wastewater transport and disposal costs. Reuse of soil/aggregate as fill was not considered but would further improve economics by avoiding disposal. For year-round operations an enclosure may be needed to prevent freezing. Mobile, scalable units offer flexibility but must still have sufficient incoming supply for economic viability.

The final report of Wet Spoil Remediation Phase 2 was completed and released to OTD members in June 2024.

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OTD Operations Technology Development

Removing Water Vapor Impurities

The objective of this project is to develop and test a desiccant moisture removal system for use in local distribution systems.

Project Description

Moisture can enter a distribution system in various ways. Solutions are needed to remove moisture at the service connection level. A desiccant system designed for this application must consider maintenance requirements, longevity, and cost. Desiccants that could be used for moisture removal were tested in the prior phase. Two candidates identified from phase 1 which had less odor fade potential, and good moisture removal performance will be the focus of phase 2. A modified test rig will be used to evaluate desiccant performance with gas, to inform development of a prototype moisture removal unit for lab and field testing.

Deliverables

Deliverables for this project include a modified test plan and rig, moisture removal test results and data analysis, a prototype for lab and field testing, and a final report.

Benefits

This system has the potential to reduce potential service interruptions and maintenance required to control moisture in a cost-effective manner.

Technical Concept & Approach

Specific tasks in this project include:

Modify Test Rig & Develop Test Plan

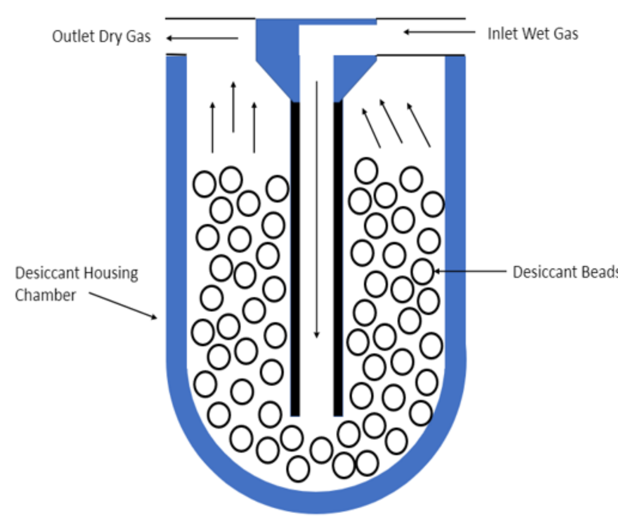
The team will modify/fabricate a test rig to test with natural gas (desiccant performance differs from air), develop safety HAZOP JSA (GTI Energy campus facility for meter, regulator component testing, modular burner flare), and humidify gas to test in range of field data provided by an operator (127-690 ppmv).

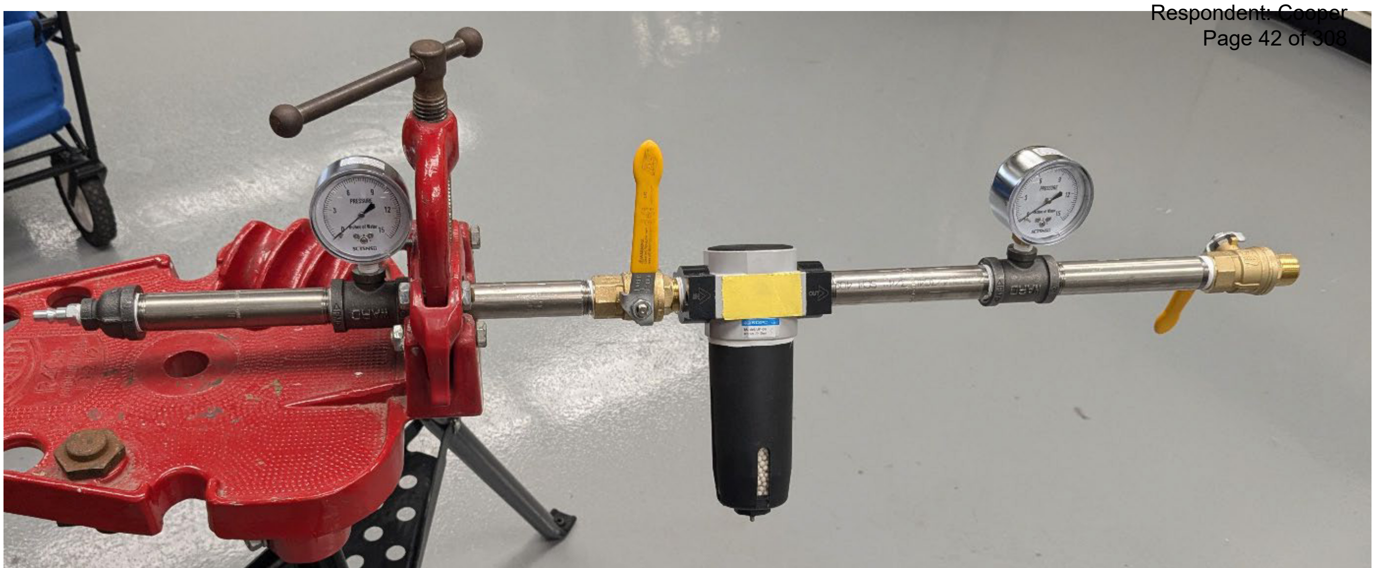
Moisture Removal Testing & Data Analysis

The team will test/analyze Molecular Sieve-3Å and consider Indicating Drierite™ identified in the Phase 1. The team will also perform accelerated flow testing and extrapolate data to full saturation as required and evaluate maintenance interval.

Develop Prototype for Lab & Field Testing

Prototype design parameters include sizing with desiccant quantity, estimated changeout frequency (select deployment application), safety shutoffs and other features for handling water slugs, and a bypass to facilitate maintenance changeout. The team will draft recommendations for desiccant management/regeneration will be drafted. Once the design is complete, the team will fabricate a prototype unit and test it in the lab. The prototype will be refined based on these results before being deployed for field testing.





Test rig modified to include pressure gauges

Results

The project team is focusing on the two desiccants previously identified as having the least odor fade, these same two desiccants were used in initial testing to evaluate pressure drop.

The team performed initial tests using air to evaluate pressure drop across the desiccant bed. The test rig from the first phase of the project was modified to include pressure gauges of the appropriate range (0-15 in W.C.). Inlet pressure was regulated to 7 inches water column and the flow was controlled with a ball valve.

Though the flow rate was not measured in this test, the valve was slowly opened and closed to simulate different flow rates through the desiccant. The team repeated this test for the two different desiccants mentioned above, both completely dry for the test. Both desiccants yielded the same result of minimal pressure drop.

Status

The team will repeat the pressure drop test with an inline flow meter so the flow can be adjusted to 500 SCFH and the pressure drop recorded for various flow rates. If any pressure drop is acceptable to sponsors, the desiccant will be hydrated to observe the effect of saturation, since the desiccant will gain weight/volume as moisture is absorbed/adsorbed by the desiccant. There is some concern that this increased mass/volume may impede flow as the desiccant becomes saturated.

Odor fade observed in the first phase will be confirmed with retesting and evaluated to determine if this is acceptable for field service conditions. Should these further tests indicate that sufficient service pressure can be maintained as the desiccant becomes saturated and observed odor fade is acceptable, next steps will be to design and test a field-scale prototype with gas.

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Product Performance and Validation Program

The objective of this project was to create a program to validate product performance through testing to confirm that the manufacturers still produce high-quality material meeting industry requirements.

Project Description

The industry standard requirements are well-defined to validate product performance at the design level. They include comprehensive testing protocols and methods that products need to be subjected to before introduction to the market or when critical changes to a product design or material occur. However, production process changes that occurred over the course of product life are not validated by manufacturers due to lack of requirements and cost. This project addresses this gap by offering ongoing product validation testing following the requirements of codes and standards. This project compared the performance of similar products from various suppliers to help make informed decisions about their usage.

Deliverables

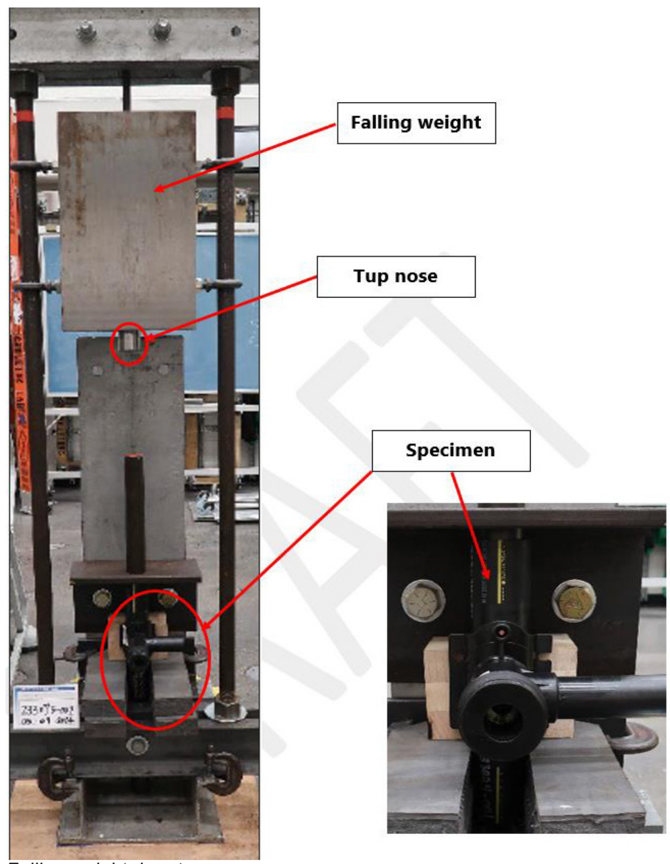
Deliverables for this project included test results from product assessments and a final report.

Benefits

The program developed through this project validates products and materials to ensure that they meet industry requirements. This standardized and centralized process reduces cost for project sponsors. Product performance information was shared with sponsors to inform their product choices and evaluate their suppliers.

Technical Concept & Approach

The primary task for this project was testing. This included sample collection/procurement, sample preparation, and testing. The number of samples to be prepared was determined based on testing and evaluation needs discussed and finalized with the project sponsors.



Falling weight drop tower

Exemplar failure location of 2"x1-¼" HDPEtapping tee

Results/Status

The team tested electrofusion and mechanical fittings/joints:

Electrofusion Fitting Assemblies

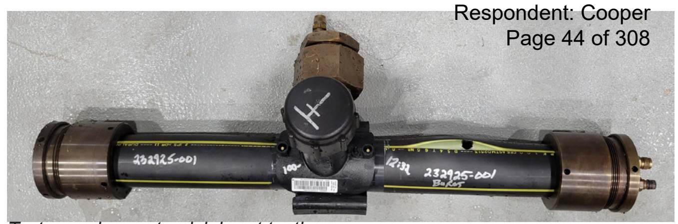
The team evaluated and tested electrofusion fittings from two different manufacturers. The ASTM F1055-16a(2022) Standard Specification for Electrofusion Type Polyethylene Fittings for Outside Diameter Controlled Polyethylene and Crosslinked Polyethylene (PEX) Pipe and Tubing was used as the governing standard for design compliance.

Pipe and fitting specimens were conditioned prior to joining at the minimum and maximum pipe temperature allowable for fusion, as recommended by the fitting manufacturer, for at least 16 hours.

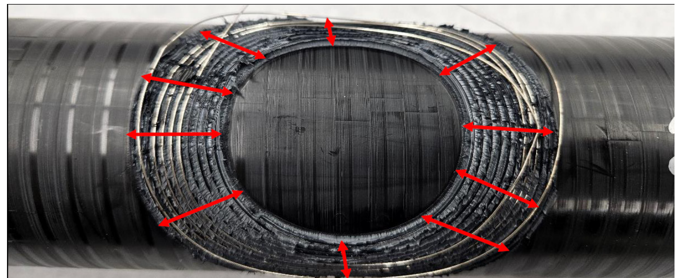
Electrofusion Joints Testing

Tests for the electrofusion joints included: Minimum Hydraulic Burst Pressure Test, Sustained Pressure Test, Tensile Strength Test (Coupling Type Joints Only), Fusion Evaluation Test, Impact Resistance Test (Saddle Type Joints Only), and Decohesion Test (Saddle Type Joints Only). All tested joints met the requirements.

Additional decohesion tests were performed in general accordance with ISO 13956:2010 (Plastics pipes and fittings – Decohesion test of polyethylene (PE) saddle fusion joints – Evaluation of ductility of fusion joint interface by tear test) at 73.4 ± 3.6°F and a pull rate of 2 in./min. All of the tapping tee assemblies tested passed. Note that this test is not part of the ASTM F1055 design requirements.



Test sample -post quick burst testing



Radial ductility as shown by red arrows

Mechanical Fitting Assemblies

The team evaluated and tested mechanical fittings from two different manufacturers. The mechanical fittings were evaluated and tested in accordance with ASTM F1924-19 Standard Specification for Plastic Mechanical Fittings for Use on Outside Diameter Controlled Polyethylene Gas Distribution Pipe and Tubing.

Fitting and pipe samples were assembled either by the manufacturer or in accordance with their instructions.

Mechanical Joints Testing

Tests for the mechanical joints included: Elevated Temperature Sustained Pressure Test, Tensile Strength Test, Temperature Cycling Test, and Constant Tensile Load Joint Test. All tested joints met the requirements.

The final report of the Product Performance and Validation Program was completed and released to OTD members in November 2024. In the fall of 2024, the next phase of testing was proposed and funded. The project team is in the process of scheduling a kick-off meeting and preparing the scope of work.

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Validation of Non-Destructive Testing (NDT) Technology for PE Pipe

The objective of this project was to develop "good" and "bad" reference butt-fusion joints for evaluating and validating the claims of commercially available non-destructive testing (NDT) technologies for PE butt-fusion joints.

Project Description

The project aimed to evaluate and validate the claims of commercially available non-destructive testing (NDT) technologies for PE pipe and fitting joints. This evaluation was originally intended to include heat fusion (e.g., butt and sidewall) and electrofusion (e.g., couplings, branch fittings, service tees, etc.) pipe joining methods. Before that could be done, it was determined that two butt-fusion processes that consistently produce "good" and "bad" joint qualities were needed for reference joints. This project was rescoped to develop these processes.

Deliverables

Deliverables for this project included a final report detailing the development of the "good" and "bad" butt-fusion processes.

Benefits

Validation of NDT technologies for PE pipe offers LDCs many benefits, some of these include being able to increase the quality control checks of PE connections made by field personnel and contractor personnel without having to incur the additional expense (e.g., labor, fitting expense, etc.) for actual cut-outs and reconnects, knowing the confidence level for making integrity related decisions for unacceptable pipe joints misidentified by NDT technologies, improved failure investigations, improved reliability, integrity, training, and safety, and reduced installation and construction costs.

Technical Concept & Approach

Specific tasks in this project included:

Identify NDT technologies to evaluate

This task included identifying different NDT technologies and vendors to include in the originally planned validation testing. Testing of NDT was abandoned after preliminary discussions with NDT vendors in which they explained that they require the evaluation of "good" reference joints before evaluating joints in the field. The project was subsequently rescoped to develop reference butt-fusion joints for validation of NDT technologies' ability to identify low-ductility joints.

Develop Butt-Fusion Processes to Consistently Generate Good and Bad Joints

This task included developing two butt-fusion processes for consistently producing "good" and "bad" joints. This task included comprehensive testing of joints via multiple test methods to confirm the consistency of the intended joint quality of each fusion process.

Results

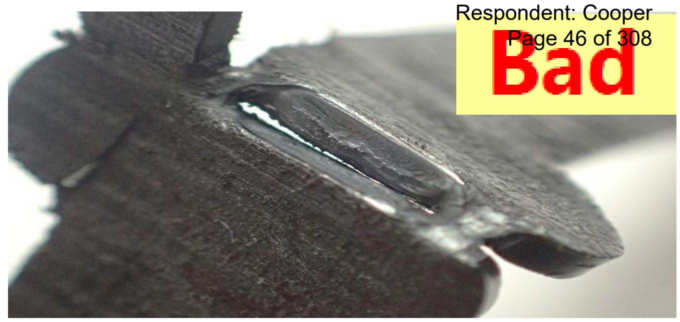
Butt fusion integrity is dependent on the degree of ductility across the fusion interface. A joint with good integrity will have sufficient ductility to absorb a deformation energy of approximately 15 J/cc (Joules per cubic centimeter), or more. This level of deformation energy causes the material to exceed its yield stress and exhibit some degree of ductile necking. A joint with poor integrity will not exhibit ductile necking and will fail at the fusion interface when it reaches the yield stress of the material, or even before the yield point in severe cases.

Two fusion processes that consistently produce the desired joint quality needed to be developed for reference joints:

Good Process – with visually acceptable fusion beads and good joint integrity.

Bad Process – with visually acceptable fusion beads and bad joint integrity in at least some portion(s) of the fusion interface.

The fusion parameters of the "good" process are in general accordance with ASTM F2620, and the fusion was performed in a manner similar to a hydraulic machine, where fusion pressure is maintained throughout the cooling time. The fusion parameters of the "bad" process that lead to low ductility are the combination of high plate



Examples of side-bend test results: ductile (left), non-ductile (right)

temperature, high initial interfacial pressure, and holding the position of the fusion machine's pipe carriages as soon as the peak interfacial pressure is reached, such that pressure relaxation is allowed.

The following tests were conducted on samples produced using both the 'good' and 'bad' fusion process:

Side-Bend Tests

Based on these results the bad fusion process has a high probability of producing sectors of low ductility and the good fusion process consistently produces ductile sectors. These results were the intended outcomes from the respective fusion processes. The overall percentage non-ductile sectors found by this test for the bad fusion process 17.5%.

HSLTT Tests

The high-speed low-temperature tensile (HSLTT) test represents a severe loading condition on the fusion interface. In this evaluation, eight (8) tensile specimens were taken from each joint. In the bad process joints all have at least one (of 8) specimen that fails below the energy-to-break level. The overall percentage non-ductile sectors found by this test for the bad fusion process 25%.

Tensile Tests

The tensile test was able to find the portions of the joints that failed prior to the yield stress – this is indicative of the how the "bad" fusion process produces sectors with very poor performance. The tensile test data was process in an identical manner to the HSLTT test data, where the energy to break was extracted by integrating the stress versus reference strain curve. The overall percentage non-ductile sectors found by this test for the bad fusion process, 20.8%.

Drop-Weight Impact Tests

All the joints from the good and bad processes exhibited ductile deformation of the pipe and no significant deformation at the fusion interface. Despite the drop-weight impact test's inability to discern between the good and bad joints, this effort serves as an example of how joints with sectors of low-ductility can withstand certain impact loading conditions.

Burst Tests

Burst (pressure) tests were performed and as expected, none of the joints failed under the burst test.

LTHS Tests

Four of six of the bad process joints have failed, and none of the good process joints have failed. All the joint failures were located at the fusion interface. The apparent performance of the failed joints was in line with the reference pipe's ductile performance. However, it is important to note that the failures of the bad process joints were at the fusion interface, which indicates that the driving stress of these failures was primarily the stress in the axial direction of the pipe, not the hoop stress. In other words, in an LTHS test of a good butt-fusion joint, the pipe wall should fail before the butt-fusion interface.

The development of these good and bad processes now enables the creation of joint sets for round-robin blind testing of NDT technologies. The results of the work in this project have also provided evidence that careful control of the fusion process leads to high success in achieving ductile joints, as can be seen from the consistently good performance of the good fusion process. Through control and datalogging of the fusion process, the needs of quality assurance, traceability, and integrity management can be satisfied.

The final report of Validation of Non-Destructive Testing (NDT) Technology for PE Pipe Phase 1 was released to OTD members in July 2024.

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Commercialization of new version of meter removal tool

The objective of this project is to commercialize the prototype Meter Removal Tool developed under project 5.21.a

Project Description

The goal of this project is to commercialize the prototype meter removal tool developed under OTD project 5.21.a, which was designed to loosen seized meter nuts for meters in capacity classes 250 and 400, connection sizes up to 30LT, for meter swivels with center-to-center (C-C) spreads of 6 and 8.25 inches. The commercialization efforts will include field demos of the prototype tool at OTD sponsor sites, any final design refinements, and demonstrations/promotions of the production tool at gas industry events.

Deliverables

Deliverables for this project include a field demonstration at OTD member companies, documented user feedback from the trials; design improvements resulting from the documented feedback from field demo trials; a production tool that is on the market with patent applications filed; and a final report.

Benefits

A tool that can effectively and efficiently loosen seized meter swivel nuts will reduce worker injuries and will save time by reducing the amount of meter set rebuilds and leak repairs caused by excessive or unsuccessful wrenching methods.

Technical Concept & Approach

Specific tasks in this project include:

Field Demos

The work in this task includes sending prototype versions of the tool to OTD member companies for field trials and user feedback.

Refine Tool Design

The work in this task includes working with our industrial tool manufacturing partner to refine the prototype design based on user feedback from field demonstrations.

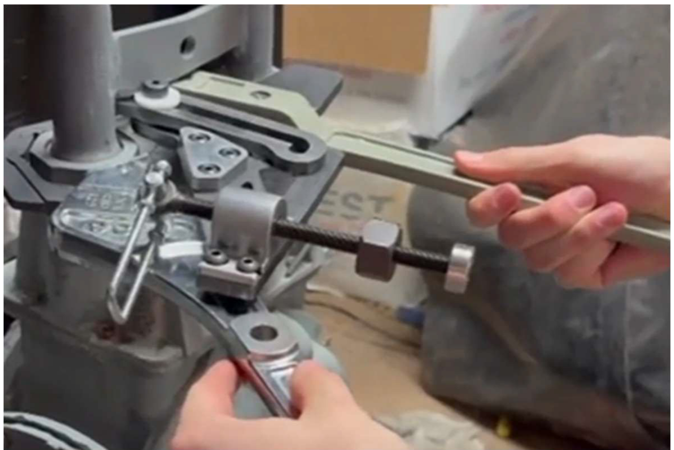
Commercialize Tool

The work in this task includes efforts required to bring this tool to market, including but not limited to working on protecting intellectual property and filing patents, as well as working with the tool manufacturer to conduct promotional and demonstration events at industry conferences and venues.

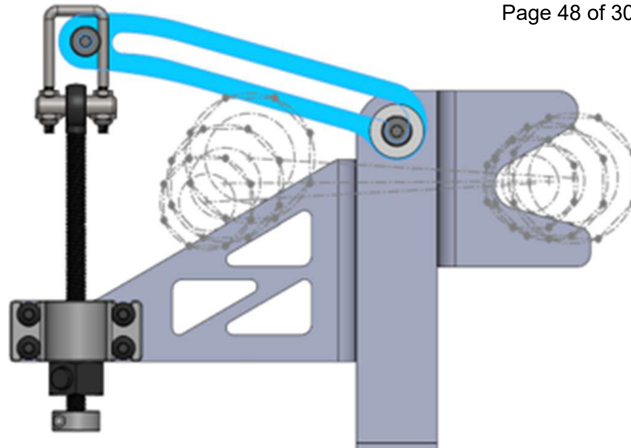
Results/Status

This phase of this project kicked off in Q4 2024. The final design from the previous phase of the project (Prototype 12) was modified into the refined Prototype 12.1. At the kickoff meeting with sponsors, the design and operation of Prototype 12.1 was reviewed. The Prototype 12.1 enhancements included changing the thread shape to make it more effec-

JSP Prototype 13 Components



Pivot Bolt for Pivot Arm on GTI Energy Prototype Yoke 2.2 colliding with low clearance meter bar



CAD of Prototype Yoke 2.3

tive, making the anchor plate easier to install, and the addition of new spring-loaded magnetic collar inserts so that the tool could better accommodate various pipe swivel diameters by clamping onto the same collar OD. However, testing showed that the magnetic collar inserts were too tall and could not seat in the proper position on offset meter swivels. Because of this, the magnetic collars could not clamp properly and therefore did not close enough to be effective. Additionally, the loose magnetic collar components could easily get lost by the operators, which was a significant design drawback.

In parallel to Prototype 12.1, the project team developed a new alternative tool design referred to as the one-clamp “Yoke” design, where an open right side is pushed into the outlet meter swivel and then clamped in place onto the inlet meter swivel. The project team produced several variations of the Yoke design and found that the Yoke concept design was easier and more intuitive to install on typical meter set assemblies (MSAs) than the anchor plate of Prototype 12.1. It was also found that Yoke concept design was able to securely tighten onto a variety of meter swivel sizes due to its design and use of a threaded rod and angled face to secure the device to the meter set assembly, allowing for greater variation in meter assembly configurations and sizes.

Both Prototype 12.1 and the Yoke design were discussed with project sponsors, and the project sponsors expressed preference for the Prototype Yoke design over Prototype 12.1 due to it being easier to install/clamp and unclamp/remove, with less components needing to be operated, while also being able to clamp a wide variation of meter swivel sizes. Based on testing and feedback on the variations of the Prototype Yoke design, Yoke 2.2 was chosen for further development.

The team began developing a design for Prototype Yoke 2.3 which will incorporate further refinements to reduce the overall height of the tool so it can fit into more meter set variations, specifically with low meter bars. In 2025, the team plans to produce manufacturing-grade prototype tools based on the Yoke design and share them with sponsors for field demonstration testing and evaluation.

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Operations Technology Development

Evaluation of the CoSMiC Eye Satellite-Based Pipeline Right-of-Way Monitoring System

Researchers conducted a technical review and evaluation of the CoSMiC Eye satellite-based pipeline monitoring system. CoSMiC Eye completed successful field trials in Germany and prepared field trials for France and Italy. This project evaluated its use in North America and assessed 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-referenced object that can be displayed as a marker on a map at the location of the detected activity.

Since the CoSMiC Eye system also employs 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 was to conduct a technical review and evaluation of the CoSMiC Eye system. This project evaluated its use in North America and the potential benefits it offers.

Deliverables

This project provided the following deliverables:

A report comparing other technology that uses satellite imagery to monitor pipeline safety and integrity and threats to pipeline operations.

A report that details the results of field trials involving European gas companies and the conclusions on the benefits of CoSMiC Eye in pipeline integrity management.

A report on the results and conclusions of field trials of CoSMiC Eye conducted with North American gas companies.

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

An older image (left) and an updated image (right) where the white dot in the right image has been identified as a potential threat.

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 identified and evaluated 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.

This project provided an evaluation of the use of CoSMic Eye by five European gas companies and the preparation of a case study for each.

In-service North American field demonstrations were a critical aspect of this project. These demonstrations were conducted with the participation of OTD companies. An appropriate pipeline segment and length was identified, and the CoSMiC Eye system was tasked with monitoring it for a defined period of time. During the six month monitoring period of the demonstration, the team met every 2 weeks to review detected activities with the gas company. If a ROW threat was detected, an alert was issued to the gas company.

Results/Status

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.

The project team did a field evaluation of the CoSMiC EYE system to assess its ability to effectively monitor a pipeline ROW for third-party interference (TPI). From August 2022 through February 2023, CoSMiC-EYE monitored a segment of pipeline in northwest New York State. Monitoring data was summarized by Orbital Eye every two weeks, and all newly detected activities were reported to the operator in the CoSMiC-EYE application, along with optical satellite data for the locations where activities were detected.

The operator then evaluated and classified all the detected activities in the CoSMiC Eye application, and decided whether any further action or investigation was needed. CoSMiC-EYE system identified 81 TPIs. These TPIs were evaluated by the operator and categorized into one of 5 categories: construction works; storage building/shed; nothing relevant; too far from Pipeline Centerline; vegetation clearance.

The team concluded that COSMiC-EYE can be an economic monitoring method, as effective or more effective (in situations such as bad weather and during night hours), than aerial surveillance. The monitoring frequency of CoSMiC Eye, which occurred every two weeks, provided benefits over the current monthly aerial surveillance. Only a short training period was necessary to learn how to use the CoSMiC-EYE application and evaluate the reported activities over the pipeline ROW.

Further evaluation of the CoSMiC-EYE system is needed in comparison to ROW monitoring by aerial reconnaissance, vehicular monitoring, and observation by foot patrol. The advantages of CoSMiC-EYE in terms of cost, frequency of data reporting, and accuracy need to be further evaluated.

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

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OTD
Operations Technology Development

Development and Evaluation of the CoSMiC Eye Satellite Based Pipeline Monitoring System

The objective of this project was 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 Orbital Eye's CoSMiC Eye monitoring system for detecting changes in class location of buildings near the pipeline. The CoSMiC Eye satellite-based pipeline monitoring system uses both radar and optical imagery to also 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 by radar, 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.).

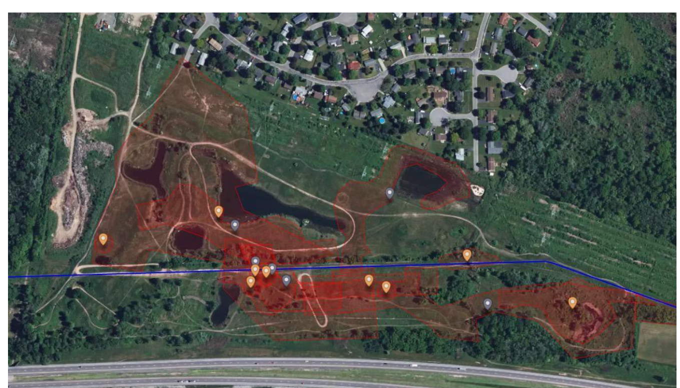
When the radar data indicates an activity in the pipeline ROW, the CoSMiC Eye system automatically tasks an optical satellite to acquire optical imagery for that site. For changes deemed relevant by the CoSMiC Eye system, an alert is issued to the pipeline operator. An example of this functionality can 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

This project provided two OTD sponsors with six months of continuous monitoring of selected pipeline ROWs. Orbital Eye provided 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. Orbital Eye also provided technical support, setup, installation and hosting at the field demonstration participant's site of the CoSMiC Eye service running in the Orbital Eye cloud. A final report detailing the results and conclusions of the field demonstrations of CoSMiC Eye and analysis of the pipeline segment that was monitored and any buildings or structures detected was also delivered to project sponsors.

Benefits

The value of this system is the ability to harness satellite data and machine learning algorithms to detect potential threats to the pipeline ROW and provide utilities an opportunity to address these threats before they become a larger issue, at a greater frequency than helicopter or vehicular monitoring, and at a cost less than helicopter or vehicular monitoring. The use of the CoSMiC Eye system is also not weather or time of day dependent. Strategies that are cost effective, can monitor a pipeline in all weather conditions, day or night, and identify a wide range of ROW threats would be of great benefit to the gas industry.



Example of multiple TPIs that belong to one unique activity.

Technical Concept & Approach

Specific tasks in this project included North American Field Demonstration for which an area was identified, and the CoSMiC Eye system was tasked with monitoring it for a defined period of time. Two OTD sponsors participated in the demonstration and sections of pipelines were monitored for six months, during normal construction season (April though October).

Results/Status

The project conducted a large-scale field demonstration of the CoSMiC-EYE system by monitoring pipeline sections in both operator's service territories. The demonstration focused on pipeline right-of-way (ROW) monitoring and class location determination and lasted six months (April through October 2024).

For both field demonstrations individual third-party interference (TPIs) were sometimes combined into a single grouping called a Unique Activity. A unique activity is a single activity, such as the construction of a multi-building residential subdivision, that might include several TPIs, such as a construction trailer, excavation equipment, stock piling of construction material, etc. Along with TPIs, Monitored Events (MEs) were also identified. A Monitored Event is an area of ongoing construction activity that needs to be monitored and reported on whether a TPI was detected.

During the ROW Monitoring for the first operator, Unique activities were classified as either a Threat or No Threat or were not classified at the time of the report. Most detected events were classified as No Threat, and further classified into 5 categories: Vegetation related; Ground works; Other; Storage; and No event. Most detected events were classified as vegetation related events, followed by ground works events.

During the ROW monitoring for the second operator, the unique activities were further classified into 5 cat-egories: Vegetation related; Ground works; Other; Storage; and No event. Ground works and Vegetation related each accounted for 42, 40% of the total, unique activities.

Overall, the system produced a low false positive rate and allowed remote initial threat determination based upon satellite radar and optical data. This allowed for early determination if a site visit was necessary to confirm TPI classification. These demonstrations were considered successful, and the project team met separately with both operators to review the results and collect user feedback.

Image showing new excavation activity.

Photo image of detected excavation activity.

The final report of Operational Demonstration and Evaluation of the COSMIC-EYE Satellite Based Pipeline Monitoring System Phase 2 – Pipeline Right-of-Way Monitoring for Class Location Designation was re-leased to OTD members in January 2025.

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OTD Operations Technology Development

Hydrogen Blending Impact on Aldyl-A and HDPE Pipes

Research was conducted to develop a lifetime-prediction and risk model for Aldyl-A and vintage (M8000) high density polyethylene (HDPE) pipes pressurized with a natural-gas/hydrogen blend.

Project Description

Gas utilities are increasingly interested in researching hydrogen blend impacts on existing infrastructure. The objective for this project was to develop a lifetime-prediction and risk model for Aldyl-A and HDPE pipes pressurized with a natural-gas/hydrogen blend. Aldyl-A and M8000 pipes are common pipe materials found in natural gas distribution systems.

Deliverables

The deliverables for this project were a lifetime-prediction model for Aldyl-A and M8000 pipe pressurized with a natural-gas/hydrogen blend and an associated Aldyl-A and M8000 material risk model.

Benefits

This project provides a better understanding of the impact of hydrogen blends on the existing PE infrastructure, which 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.

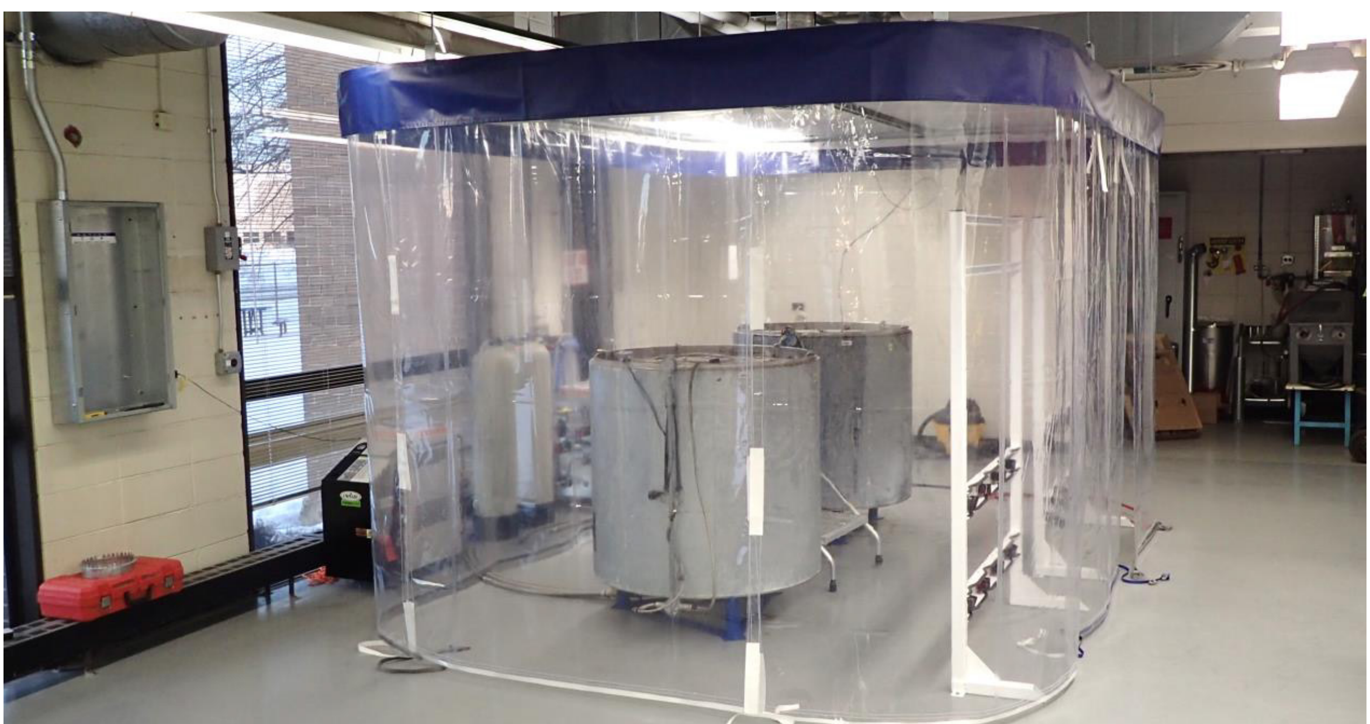
Technical Concept & Approach

Various tests were conducted on Aldyl-A and M8000 samples:

Long-Term Hydrostatic Strength (LTHS) Tests

LTHS tests were performed at three temperatures, three pressures per temperature, and three replicates per temperature/pressure combinations, with methane and methane/hydrogen blend. This task also included a visual examination to count any existing SCG (slow crack growth) cracks.

Dynamic Thermal-Mechanical Analysis (DTMA)



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

Step-DTMA was 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 were 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)

Initial OIT tests were performed before and after the LTHS testing to measure stabilizer consumption with and without hydrogen blending. However, results indicate that even a single pipe specimen has notable variability in OIT results. This variability makes OIT testing a challenging assessment method because a trend could not be extracted from the data. Therefore, the project team decided, with the approval of the sponsors, to abandon the remaining OIT scope of work.

Cross-Polarized Light Microscopy (CPLM)

This test is used to 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 was 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 was performed on every pipe specimen before testing.

Results/Status

The project kicked off test-rig construction, Aldyl-A pipe-specimen inventory, and material testing in 2021. The research team obtained a sufficient number of Aldyl-A pipes from the pre-1983 vintage. Pressure test-ing, microscopy examination of the pipes, tensile tests, DTMA tests, OIT, and LTHS testing of Aldyl-A samples were conducted.

The final reports on the Aldyl-A and M8000 testing and results were completed and released to OTD members in September 2024.

Results for Aldyl-A pipe were ultimately inconclusive with different statistical approaches suggesting different conclusions. For example, when comparing all samples with 20% hydrogen blend to those with 100% methane as groups, there were no obvious difference in the equivalent stress intensification factor (SIF) distributions. On the other hand, when comparing them within specific SIF bins, the 20% hydrogen blend samples showed 5-16% higher mean SIFs than the 100% methane samples. Other analytical approaches also produced mixed results. More empirical testing is necessary for confidence in these results.

The long-term hydrostatic strength (LTHS) tests performed on M8000 pipes in this project found that samples tested with 20% hydrogen blend had apparent improvement in slow-crack-growth performance relative to 100% methane. Effect size analysis showed an increase of 60% in mean expected time-to-failure for the 20% hydrogen blend test group relative to the methane group, in the slow-crack-growth failure mode. However, this effect was found on a small sample set that needs to be substantiated with additional testing.

The finding of this project with respect to both pre-1983 Aldyl-A and M8000 pipes suggests system operators need to be aware of the possible effects that a 20% Hydrogen blend has on creep performance. Addi-tional sampling and testing is recommended to provide sufficient statistical significance to be able to draw definitive conclusions for each respective pipe material.

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OTD Operations Technology Development

Assessment of FFS Performance Envelope Reduction from Hydrogen Embrittlement

The objective of this project was 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 poten-tial impacts on their specific pipe materials.

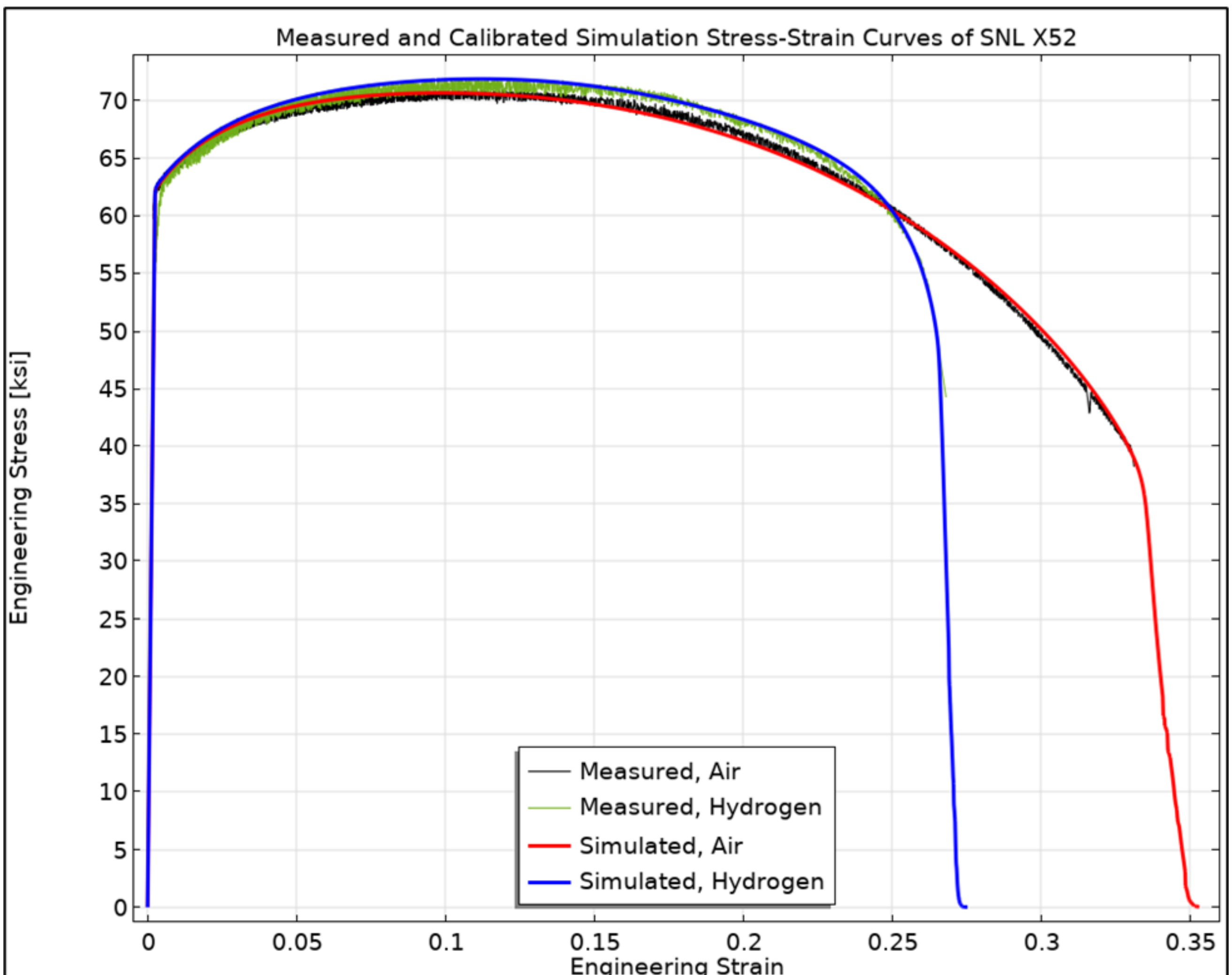
Project Description

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

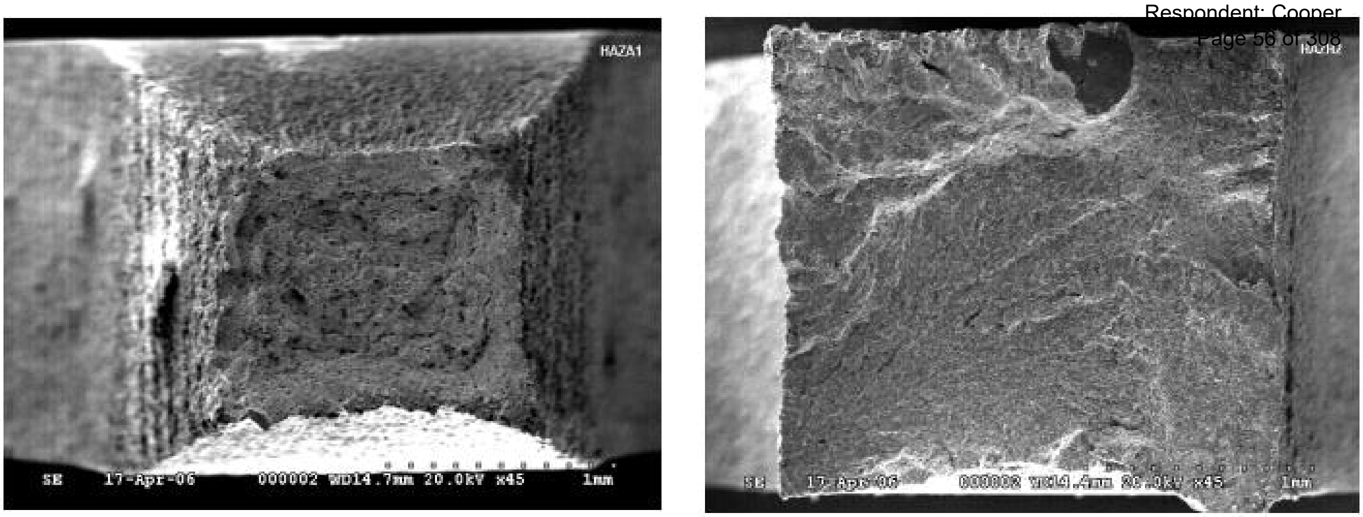
The effect on pipeline fatigue, strength and hydrogen embrittlement needed to be better understood by operators and the influence of these on the pipeline FFS.

Deliverables

The project delivered a final report that includes a Hydrogen Embrittlement (HE) performance envelope reduction assessment based on SNL's steel material data, a discussion on the implications of HE performance reduction on integrity management, and a recommended material testing plan for input into hydrogen FFS assessments.



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



Low Magnification Scanning Electron Micrographs showing reduction in fracture surface area from Alloy A106 grade B HAZ tested in (Left) Air and (Right) 1500 psig Hydrogen.

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 provided 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 was intended 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 used SNL's steel material data and performed an assessment to understand the impact of hydrogen embrittlement, based on established fitness-for-service calculations. The implications of the assessment were then 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/Status

The project team developed an input matrix for Sandia National Lab's Hydrogen Extremely Low Probability of Rupture (HELPR) software tool based on test data from SNL. HELPR was used to perform probabilistic fatigue and fracture analysis for pressurized cylinders. The team reviewed and confirmed that the software performs as intended and is capable of producing fatigue calculation examples.

The team validated the fitness-for-service (FFS)/finite element method (FEM) approach presented in simulations of hydrogen embrittled steel. The importance of accurate pipeline steel properties for FFS assessments was highlighted, concluding that each material needs to be specifically characterized for FFS assessments.

Ongoing projects are addressing specific steel properties, with and without hydrogen, and attempting to improve surrogate models and non-destructive surface evaluation. This will reduce the effort to obtain material properties needed to perform FFS assessments on operational pipelines.

The final report on Assessment of FFS Performance Envelope Reduction from Hydrogen Embrittlement was completed and released to OTD members in December 2024.

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

The objective of this project is to examine the effect of hydrogen blended natural gas on the performance of domestic gas meters, service regulators and other components.

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 certain hydrogen concentrations, gas meters and regulators will maintain their metrological properties and operational safety during long-term operation.

This project involves a collaboration with parallel OTD project 7.21.j "Assessing Performance Impacts of and Leak Rates on System Components". The primary 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 project will be valuable to participating gas utilities in several key ways. First, it will provide understanding of the long-term impact of using hydrogen-blended gas on the durability of gas meters and service regulators. Second, the project will deliver technical insights backed by high-quality testing data that can assist utilities in deciding on large-scale implementation of blended gas initiatives in their service areas. Third, the project will generate test data specific to gas meters and regulators that are widely used in the North American gas industry.

The testing will address critical industry concerns about the performance of service regulators, gas meters, and other MSA components when exposed to hydrogen-blended natural gas. Gas operators and regulators require confirmation that within certain hydrogen concentrations, long-term operation of these components will be ensured without compromising their metrological properties and operational safety.

Technical Concept & Approach

Specific tasks in this project include:

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 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

Two Test Rigs, each with nine Independent Meter Set Assemblies, will be used in testing. Each meter set assembly has a regulator, meter bar, and meter valve. The team will conduct 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 flow rates between 200-300 standard cubic feet per hour

(SCFH). Diaphragm meters are examined under the 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 is approximately the 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 the 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.

Front Side of Entire Test Setup – Focusing on Both Test Rigs (Left & Center)

Results/Status

The pressure vessels have been tested and the replacement of the downstream solenoid valves has been completed on both test rigs. The team also performed a leak test on one of the test rigs. The project team identified an issue with the replacement solenoids not operating properly with the supplied voltage. The replacement solenoid valves have been installed so that all 36 solenoid coils can open properly and the team was able to move both test rigs outside and connect all of the plumbing between the various components of the test's flow loops.

The project team also completed the electrical wiring for the flow loops such that they were operational for the commissioning of the compressor and the software control system by their respective subcontractors.

The compressor and software subcontractors are working to commission their respective systems and will provide any additional troubleshooting support which is required. During further troubleshooting, the team ran into additional issues with various hardware and software components. They continue to work with these two subcontractors, as well as the manufacturer, to make the necessary modifications such that the 6-month accelerated life test can begin in Q1 2025.

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OTD Operations Technology Development

ARPA-E REPAIR Pipe Renewal Testing

For this project, researchers preformed a literature search and advanced testing to identify pipe failure modes and performance criteria for pipe-in-pipe systems. The project, co-funded by the U.S. Department of Energy Advanced Research Projects Agency-Energy (ARPA-E) program, was conducted to provide gas companies with alternative rehabilitation and structural repair systems.

Project Description

This research was conducted to validate the design and performance of Pipe-in-Pipe Repair (PIP) systems to rehabilitate natural gas pipelines in place and in service.

Deliverables

The deliverables for this program were 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, and external and internal loading test results.

Benefits

While current regulations, codes, and standards 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.

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.

Technical Concept & Approach

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 the failure mechanisms (FM) that a PIP system is expected to experience during service 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 which were shipped to the PIP installers for applying their repair system.

Results/Status

Hydrostatic Pressure Tests

This test method establishes the short-term hydrostatic failure pressure of the PIP repair when the host pipe is fully deteriorated, and the repair system is carrying the internal pressure without the contribution of the host pipe. A factor of safety of the repair system may be estimated by relating the operating pressure of the PIP specimen to its burst pressure.

The failure of the specimen is determined when instantaneous or rapid loss of pressure occurs or visible fluid leaks through the wall of the specimen.

A steel pipe was used as the host pipe with removable panels at the mid-section of the specimen and well-sealed end joint fixtures. After the installation of the PIP repair, the four panels were removed to expose the middle section of the repair. The hydrostatic pressure test was performed inside a concrete chamber. The test procedure consisted of monitoring the internal pressure and pipe deformation using video extensometer placed outside the chamber. Pressure tests to failure were initially performed on a liner product of known material

Preparation of the Repaired Pipe Sample for Internal Pressure Tests

properties to calibrate the testing procedure.

Gas Permeability Tests

The rehabilitation of pipelines transporting natural gas and methane-hydrogen blends requires low gas permeation through the repair material during its application life. Low volumes of gas would eventually permeate through the system and are either trapped between the repair wall and the host pipe or leak to the surface. The determination of the permeability coefficients of the repair from coupon samples should be performed as a part of system qualification.

The gas permeation test method consists of flowing natural gas or other methane-hydrogen blends at pressure levels ranging from 40psi-120psi (representative of typical distribution systems) on one side of a test sample placed in the permeation cell and measuring the change of pressure and concentration of gas in the other side of the chamber.

The results of this test method determine the steady-state transmission rate of the gas through the PIP repair material under normal operating conditions. Results obtained from these tests allow for quantifying gas losses expected though the PIP repairs. The gas permeation setup consisted of 3 permeation cells allowing for repetitive tests and for testing various material and gas products.

Service Connection Tests

Full-scale leak tests at end-joints and service-line connections were performed to evaluate the installation and performance of the repair system in actual service conditions. The testing setup consisted of using a 12-inch diameter steel pipe specimen with a 30-inch length. The pipe has two service-line connections of 1-¼ inch diameter at opposite sides of the pipe mid-height.

The test method evaluates disbondment of the PIP repair at the service line connection. The repair system around the life service connection is examined under cyclic pressures to evaluate if disbondment occurs. The test runs for 5 cycles from atmospheric to the maximum operating pressure for a cycle duration of 24-hours.

Gas flow is also measured through the service connection covered by the PIP repair. Gas pressure is applied inside the pipe sample at typical operating pressure and the rate of gas flow through the PIP material is determined by collecting samples and measuring gas concentration in the service line.

Service connection and disbondment tests were performed on the Sanexen liner to calibrate the testing procedure. The liner material was installed in the internal pipe surface by the supplier. One of the two service connections of the pipe sample was left uncovered by the repair material while the other connection was covered by the liner and an internal natural gas pressure of 100 psig was applied to the repair.

Samples were collected periodically to monitor the methane gas concentration leaking through the liner.

This project is complete. The final report of ARPA-E: Pipeline Encapsulation Technologies was completed and released to OTD members.

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Evaluation of Microthermal Gas Metering Technology

The objective of this project is 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 considering the proposition of transporting fuels of varying constituents. This includes low carbon based fuels such as hydrogen blended natural gas and renewable natural gas. The source of these fuels varies and subsequently so do the gas compositions. A reliable metering technology that can be easily calibrated to varying gas compositions provides an additional layer of operational flexibility to gas utilities, enabling diversification of gas quality in the network.

Deliverables

Deliverables for this project include a report detailing the test and performance results of the Micro Thermal Gas meters, and a final report.

Benefits

A technology that can accurately measure and self-adjust to varying gas compositions is beneficial to operators to transport cleaner, low carbon fuels.

Technical Concept & Approach

Specific tasks in this project include:

Test preparation

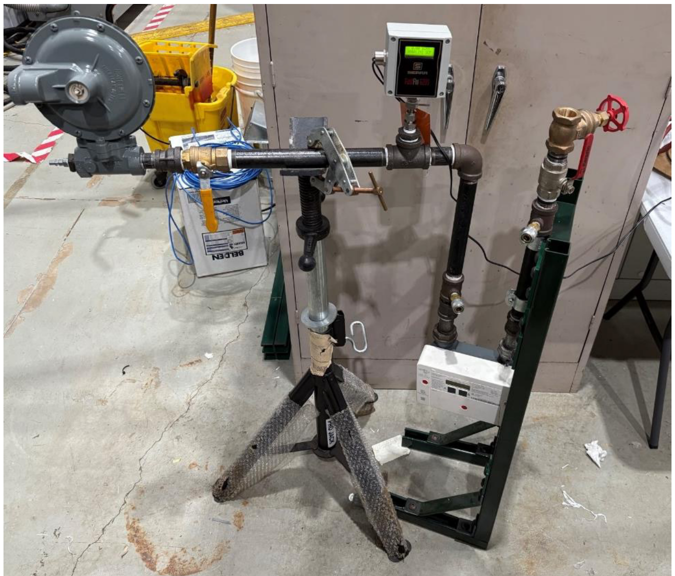
This task includes development of a test matrix to evaluate the metering technology, and field-testing locations will be identified under this task.

Evaluation of the microthermal gas metering technology

The team will set up a test rig and perform accuracy testing of the thermal mass meters using a sonic nozzle setup with air and hydrogen blended methane gas. The accuracy performance will be benchmarked with respect to the accuracy requirements mentioned in the ANSI B109.1, OIML R137 standard, and DIN EN14236 for thermal mass metering if it is publicly available.

Additionally, the project team may source meters from Europe for deployment at project sponsors' sites such as leak towns and hydrogen blend pilot

Sensirion microthermal gas meter module



Meter Capacity Test Rig

sites if there is interest in pursuing this direction. The team can help to support calibration and other testing needs during the deployment.

Data analysis and reporting

This task consists of analyzing accuracy data and comparing accuracies of samples of thermal mass meters that underwent accuracy tests at varying gas compositions. The team will conduct data analysis of the testing results and provide reports of the results of the performance tests.

Results/Status

The project team was able to establish the Blended Hydrogen Test Matrix. Three thermal mass residential gas meters were acquired to test with hydrogen-blended natural gas at a blend of 20% H_2. The team experienced difficulties in setting up the meters properly for testing in regard to getting the meters into Test Mode and finding the proper explosion proof measurement cable. Additionally, the team is working to understand how the accuracy testing with hydrogen may be accomplished to satisfy current explosive atmosphere (ATEX) certification requirements. They continue to work through these issues.

The project team developed the Air Metrology Test Matrix based on some of the standard metrology testing from ANSI B109.1, as well as some additional tests from DIN EN 14236 and OIML R137_1&2. These tests will occur with air in standard operating conditions as well as with either humidity or impurities in the gas stream, or at low battery levels. The list of tests is based on meter testing that the team has performed on other smart gas meters. The Outdoor Accelerated Life Test will be returned to the test matrix and will be performed on these meters.

The project team was able to complete the Meter Capacity Test Rig per ANSI B109.6 – Section 3.2.1.2 on 10 residential thermal mass gas meters. Additionally, the team is devising a methodology to validate the results recorded in the manufacturer's custom software environment with the prover recorded data to be able to perform the accuracy testing of the residential thermal mass gas meters. The remaining short testing and the Outdoor Accelerated Life Testing is set to be completed by Q1 2026.

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OTD Operations Technology Development

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 liquid 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 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 pipe 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.

Deliverables

The deliverable for this project is a final report which presents a comprehensive evaluation of the design and installation practices and requirements of various standards for the safe adoption of composite and alternative-steel pipes.

Benefits

The use of alternative-steel and composite systems in natural gas lines provides 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:

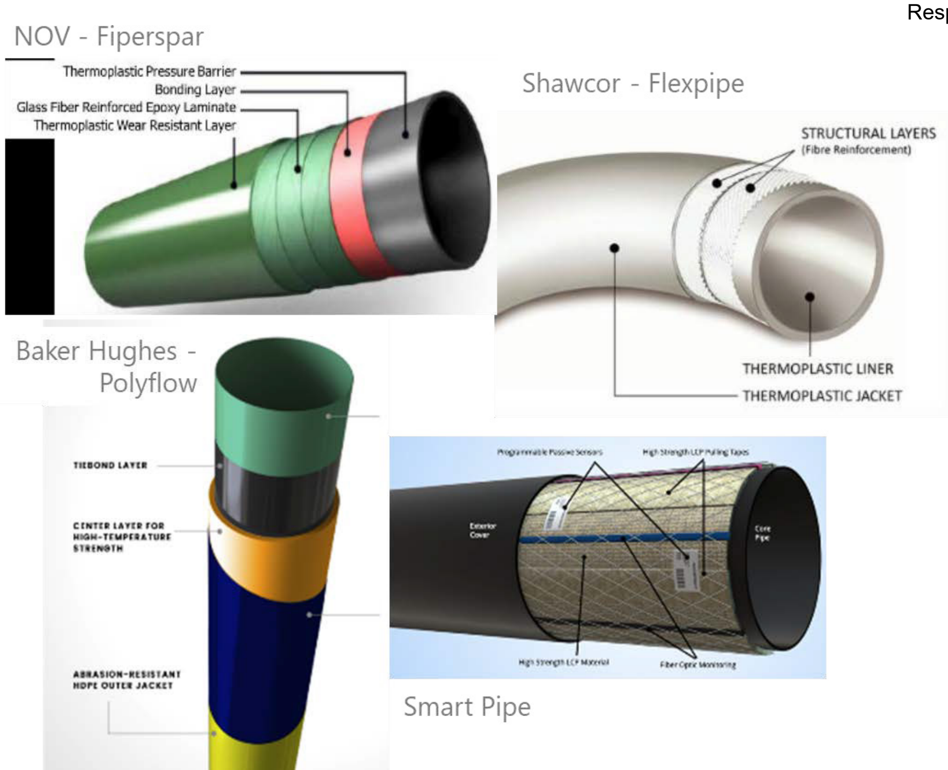
Risk-based threats identified in ASME B31.8S code are being reviewed to identify how alternate materials could affect the methods used to evaluate these threats compared to steel pipe. Recommendations were made to address knowledge gaps and alternative evaluation options were explored for each threat

Evaluating the impact of external loads, long-term performance, and degradation of the composite material properties due to varying service conditions such as pipe material, pressure, elevated temperature, and environment.

Results /Status

The final report presents a comprehensive evaluation of the design and installation practices and requirements of various standards for the safe adoption of composite and alternative-steel pipes. These standards provide a comparison of API, ASME, and international standards highlighting a comprehensive listing of material qualification, design, construction, and integrity management concerns. A detailed list of the threats and resulting defects identified in ASME B31.8S and federal codes are in the final report.

Recommendations were made to address knowledge gaps and alternative evaluation options were explored for each threat. Overall, several existing techniques that are applied for the integrity and



Composite Pipes Used in the Testing Program

risk management of conventional steel pipelines can be applied to composite piping with appropriate modifications to data interpretation, testing, and data collection procedures.

The limited recorded failures of composite pipes in PHMSA records and published data reinforce the need for operators to pay attention to design, construction, and installation procedures and practices. These procedures and practices must control pipe displacement, provide sufficient composite pipe support, and allow for restrained differential movement in response to geotechnical and operational forces. Operational practice must minimize overpressure and water slug loads. Poor design and installation initiates damage, mostly to the joints between the composite and the steel pipeline. If these damages are not mitigated, peak loading forces would accelerate deterioration.

The use of Inertial Measurement Unit in-line inspection (IMU ILI) can help identify connection misalignments and sag due to poor construction installation. Recent experience indicated that a caliper plus an IMU ILI combination tool, was most helpful to confirm that the composite pipe joints remain sufficiently supported and correctly aligned.

Industry reports which summarize the historical performance of various designs of composite piping systems also show that large pressure differentials, higher product temperatures, and greater velocities of the liquid phase content all directly increase the number of leaks and failures. Comprehensive quality control testing, inspection, and fitness-for-service methodologies need to continue to be developed. Currently, mitigation and repair are limited to removing damaged segments and replacing them with new pipe.

The final report of Using Alternative-Steel and Composite Materials in Pipeline System was completed and released to OTD members in March 2025.

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Pressure Monitoring and Alert Device for the Replacement of Token Reliefs

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

Project Description

The PIPES Act of 2020 and the associated PHMSA advisory bulletin along with corporate sustainability goals (methane reduction initiatives) are making operators look for options to reduce/eliminate methane emissions from daily operations, including full and token relief valves. In addition, operators are looking for technologies to notify of potential risks prior to a gas events occuring that could lead to over pressurization issues. The project aimed to identify and/or develop a pressure monitoring device that can be installed in place of relief valves (token or full-relief) or monitor regulator and explore other benefits of pressure monitoring in real time.

Relief Valve Assembly

Deliverables

Deliverables for this project included 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 a final report.

Benefits

A monitoring device that could quickly inform operators of pressure anomalies would have multiple benefits. Pneumatic relief valves cause methane emissions when operated. Continuous pressure monitoring can provide operators with time to act before the relief operates, reducing emissions. The relief valve still provides a fallback position if events are too rapid to react to. Continuous monitoring can also aide in preventing under pressure events.

Technical Concept & Approach

Specific tasks in this project included:

Survey Utility Requirements

The project team refreshed the AGA SOS questionnaire developed specifically for remote pressure monitor devices. The new version had questions specific to pressure relief valves and questions regarding the cost sensitivity of use cases were included. The results were used to extract a set of requirements and were reviewed to be used in the product identification task.

Build Out LoRaWAN Devices

The team used pressure monitor hardware developed during project 8.17.a. A few wireless pressure sensors were completely built and tested. The firmware for the monitors was developed and tested. The completed units operate in the 0-87 psig range; changing out the sensing element could extend this to as much as 400 psig. Fabrication of the

LoRaWAN-enabled Pressure Sensors Test Setup

mechanical nipple and threads along with additional weatherproof housings was completed.

Review/Procure Commercial Devices

The team surveyed the market for commercial off-the-shelf (COTS) wireless pressure monitors. Manufacturers were contacted for detailed information on their systems. The findings were reviewed with the sponsors to determine pressure monitor systems of particular interest.

Pressure Monitor Testing

The commercial pressure monitors of interest and the GTI LoRaWAN system were tested. A testing program was developed and shared with the project sponsors. The testing included COTS relief valves alongside the pressure monitors. The pressure monitor data was forwarded to a cloud repository for storage. Data was visualized in a dashboard that was accessible by the sponsors.

Results/Status

The project team surveyed the market around commercial off-the-shelf (COTS) wireless (non-LoRaWAN) pressure monitors. There were two primary parameters for identifying sensors for consideration. First, sensors were required to be self-contained, meaning the instrumentation, battery, and radio components must be contained within the housing of the sensor unit. Second, it was necessary for the sensors to support the requirements for Class I, Div I locations. Several candidates were identified and tested.

The test results are detailed in the final report. While the test items in this project used LoRaWAN for communication, other options such as cellular are readily available.

This project is complete. The final report on Pressure Monitoring and Alert Device to Augment Pressure Reliefs was completed and released to OTD members in January 2025.

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OTD Operations Technology Development

Gas Engineer Training Program Development

The objective of this project is to initiate development of a structured gas engineer training program, for new engineers entering the industry, on an advanced LMS system.

Project Description

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. This training program will consist 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

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 and a final report.

Benefits

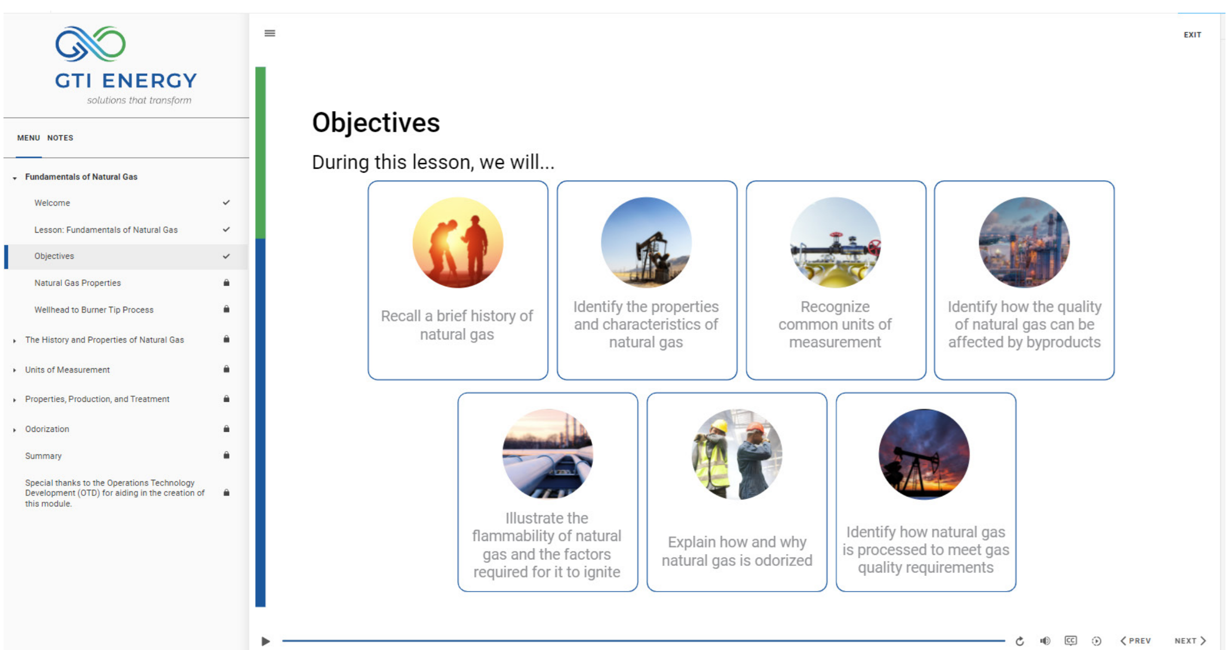
Development of a structured gas engineering training program with modern technologies will create a more engaging experience for new engineers, improving training retention and competence early in their careers. These methods require fewer hours of training and allow trainees to remain engaged while minimizing disruption to their daily work. An advanced LMS will enable training delivery on mobile devices, tablets, or computers, anytime and anywhere.

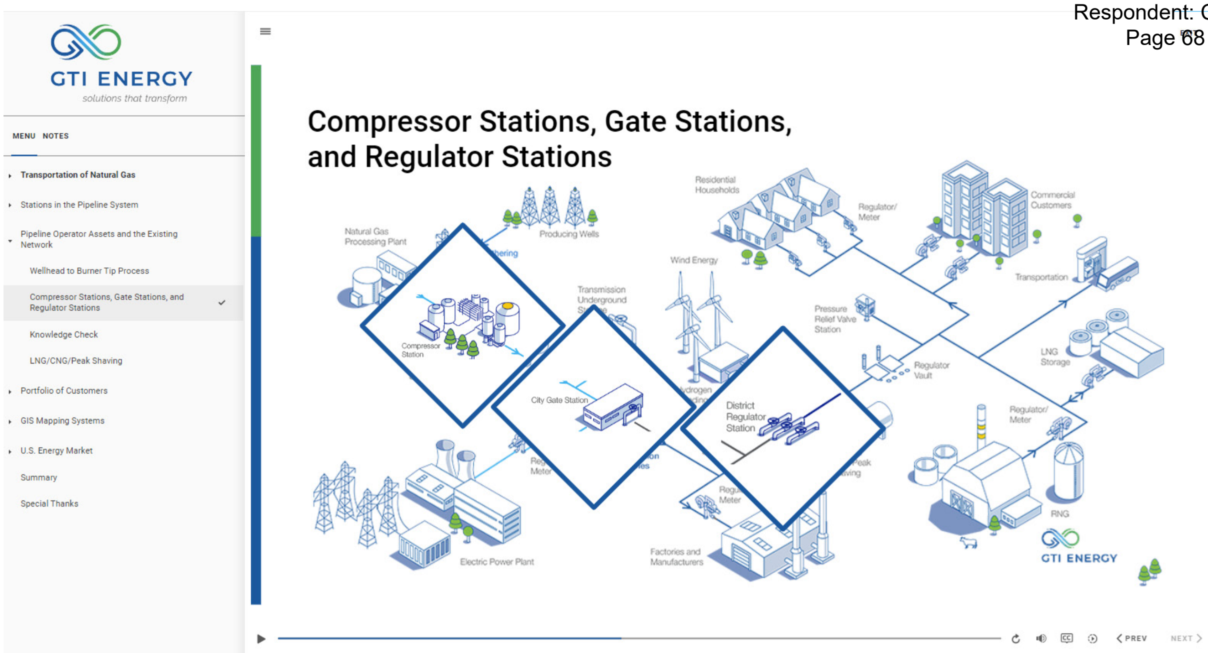
Technical Concept & Approach

Specific tasks in this project include:

Conduct Training Needs Assessment with Project Sponsors

The work in this task includes working with project sponsors to perform a training needs assessment for the proposed seven gas engineering topics 1) Introduction to Natural Gas and Engineering, 2) Safety Leadership, 3) Gas System & Strategic





Planning, 4) Gas Asset Management & Engineering Transmission 5) Gas Pressure Regulation 6) Gas Asset Management & Engineering Distribution 7) Construction & Maintenance.

Module Development

The project sponsor training needs identified on the Training Needs Assessment along with the existing GTI gas engineering training content will be used to develop the training modules, lessons, and exercises utilizing the advanced LMS system training applications.

Test and Publish the Virtual Experience

The work in this task includes testing and publishing the virtual experience for deployment to project sponsors.

Results/Status

The Storyboard content for the engineering training lessons was developed by the team and reviewed by OTD SME's across 7 primary engineering training topics for a total of 35 lessons. After the storyboard content development was completed, the team moved into the eLearning content development phase.

Due to scope changes, a total of 16 e-learning lessons were developed at the end of the project. There are 19 remaining eLearning lessons to be developed. In addition, there are other modes of learning included in the original scope that are planned for delivery but have not been started yet (e.g. Micro Video lessons, 360 Experience, Gamification, etc.).

A final report was shared with project funders in April 2025. The project team provided recommendations with regard to next steps to finish eLearning content development for the remaining 19 lessons.

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OTD Operations Technology Development

Impact of H2 Blends on Gas Service Regulator Venting

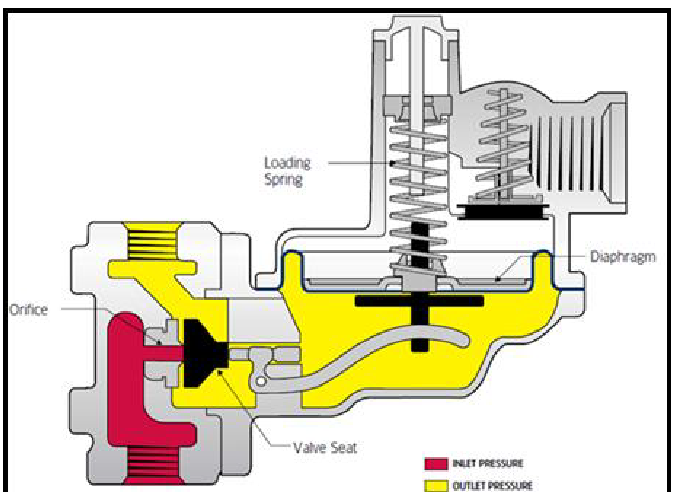
The objective of this project was to further understand the impact that hydrogen blending has on the emissions being vented from the gas service regulators.

Project Description

This project provides gas operators with valuable insights into the potential effects of blending hydrogen into natural gas distribution networks. This project utilized data from the PHMSA and OTD project 5.22.j in which gas service regulators were tested for the amounts of natural gas emissions at the regulator vents. This project explored modifying the gas density value 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 to learn and understand more about the impact on the venting of the gas service regulators that were used as part of the project.

Deliverables

The deliverable for this project was a final report including charts and conclusions for the impacts of hydrogen blends on gas services regulator emissions. This project was cost-shared by OTD, and the results of this project were presented in a technology workshop/webinar.



Single Stage Traditional IRV Gas Service Regulator Design.

Benefits

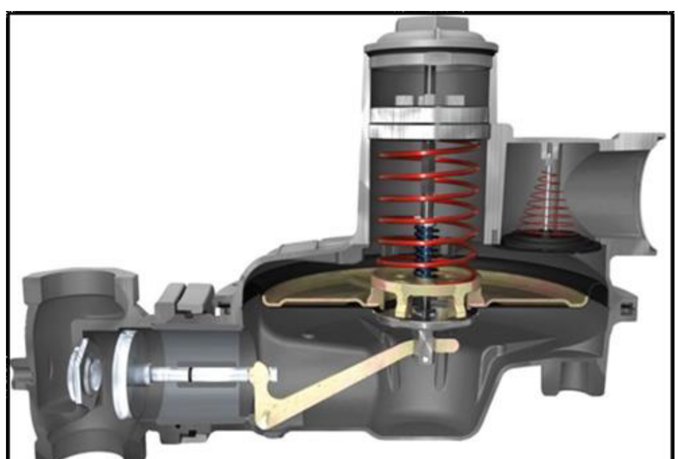
The utilization of hydrogen in gas distribution operations underscores the critical need for an examination of its impact on the venting characteristics of gas service regulators. Understanding the interplay between hydrogen blends and venting characteristics is essential for gas utilities to effectively manage their distribution systems so that utilities can make more informed decisions about their future operations. This knowledge will help to enhance efficiency and safety while embracing more sustainable practices in the gas industry.

Technical Concept & Approach

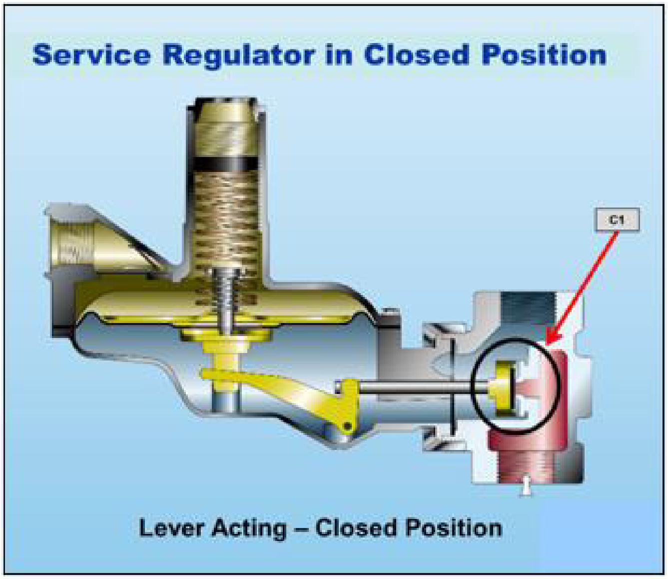
Specific tasks in this project included modifying the physical variables (gas density, specific gravity, etc.) for various hydrogen blends, plotting out the venting emissions of various hydrogen blends at different flow conditions, and performing an analysis of the data.

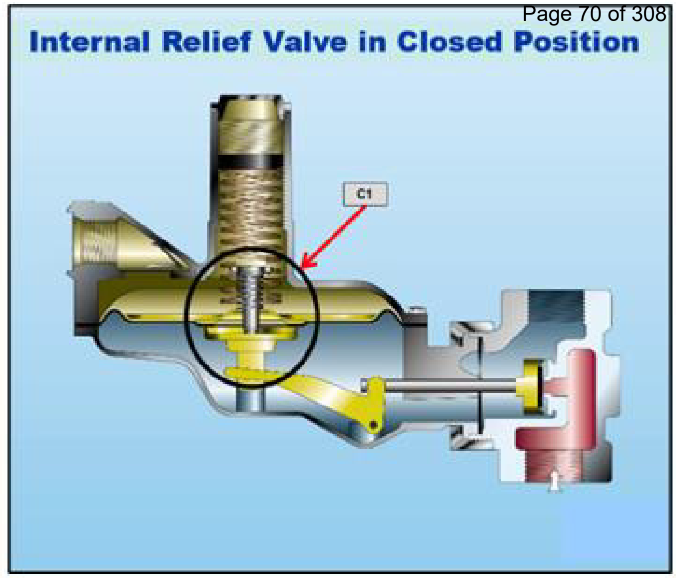
Results/Status

The project team used the data on hydrogen-natural gas mixes from the related project 5.22.J. During the data collection phase, the team ensured that

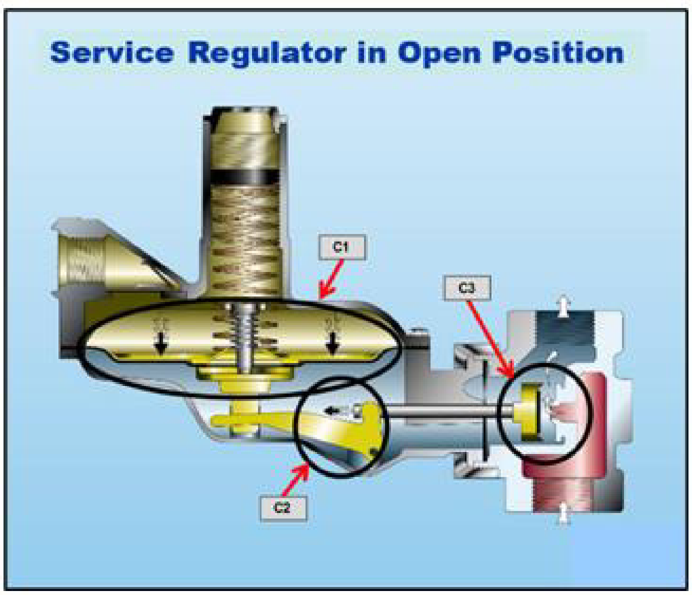


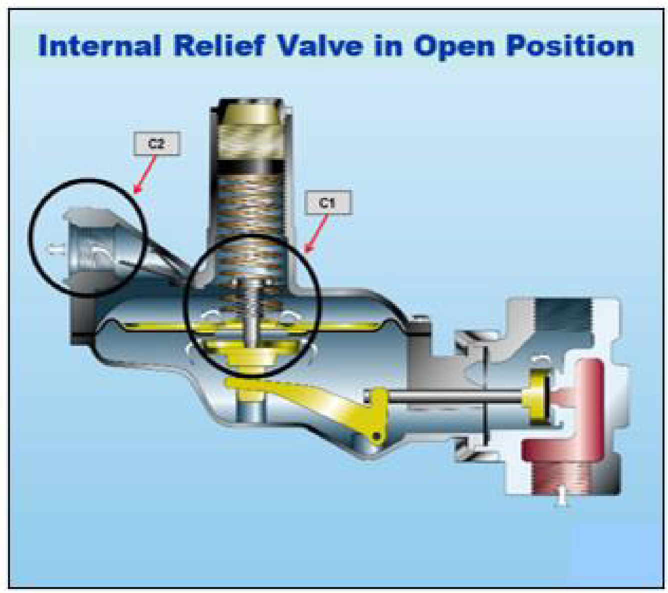
Single Stage Traditional IRV Gas Service Regulator.





(left) No Gas Usage by Customer and (right) IRV is Closed.





(left) Customer Using Gas and (right) Gas Usage Stops Raising Pressure Above IRV Set Point.

the data was accurate and complete. The data collected was then carefully arranged into standardized formats that allowed for effective analysis and simulation. The team then performed simulations to model various blend compositions and assess how they affected the venting behavior of gas service regulators.

The simulation conducted as part of this project provided extensive and valuable data on the venting behavior of Gas Service Regulators when exposed to different percentages of hydrogen in the blend. Two distinct set points were evaluated, 2-psig and 7 IWC, evaluated through the Modified Lockup Test and the Relief Test, respectively.

An evident pattern emerges from the analysis: venting emissions sharply rise with increasing hydrogen blend percentages. However, as the hydrogen percentage in the blend increases and the overall volume of emissions may rise, the proportion of natural gas in those emissions decreases significantly. This results in lower natural gas emissions, which mitigates some environmental impacts despite the overall increase in emissions volume.

The final report of Impact of H2 Blends on Gas Service Regulator venting was released to OTD members in October 2024.

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Testing of New Pietro Fiorentini Gas Service Regulators

The objective of this project was to evaluate the performance of the newly released Pietro Fiorentini gas service regulators in NR (No Relief), Calibrated Relief, and Token Relief configurations to determined safe clearance requirements and installation practices.

Project Description

This project is to evaluate the performance of the newly released Pietro Fiorentini gas service regulators in the following configurations: NR (No Relief), Calibrated Relief, and Token Relief. By leveraging the testing methods established in OTD project 5.22.J - Clearance Distances for Compact Service Regulators, the research will focus on determining safe clearance requirements and providing practical guidelines for installation by analyzing venting behaviors and performance under various operating conditions to assess how these regulators compare to other traditional regulator models. The goal is to equip gas utilities with reliable data to support flexible and safe installation practices, especially in environments where traditional clearance standards are difficult to follow. By validating the capabilities of vent-limiting regulators, this project aims to help the industry adopt innovative solutions that improve safety, efficiency, and adaptability in regulator installations.

FE25 Gas Service Regulator (Pietro-Fiorentini, 2025).

Deliverables

Deliverables of this project include reliable data about outdoor installations for gas utilities, reports on the various testing/evaluations performed, a guideline document for best practices, and a final report.

Benefits

The benefits of this project included minimizing installation limitations, improving operational efficiency, and enabling safer, more flexible practices, ultimately creating a more reliable and cost-effective approach for gas service operators.

Technical Concept & Approach

Specific tasks in this project include:

Develop a Test Plan to Measure Emissions and Clearances

A detailed test plan was crafted to assess the vent emissions and gas concentration levels of the different FE25 regulator models. This plan was designed to compare the venting behavior of these new regulators against traditional IRV models, focusing on performance at both 7 inches of water column (IWC) and 5 pounds per square inch gauge (psig) outlet pressures.

Review Installation Procedures and Clearance Requirements

The project examined the installation procedures and clearance requirements associated with the different FE25 regulator models. This involved analyzing manufacturer documentation and relevant standards from governing bodies and gas utilities to ensure proper installation practices.

Comparative Testing of Safety Clearances and Environmental Conditions

Testing was conducted in two parts. Part 1 focused

Methane sensor array with sensors positioned around the regulator vent.

on evaluating the volume of gas emitted from the regulator vent and measuring the concentration and dispersion of methane at various distances in alignment with ANSI B109.4 standards. Part 2 involved using a custom-designed test rig to measure gas levels at various distances from the vent using gas sensors, assessing the performance of the regulators in different environmental conditions.

Results/Status

The project team focused on testing three specific Pietro Fiorentini Gas Service Regulator FE25, FE25 Calibrated Relief, FE25 No Relief all tested at 7 IWC and 2 PSI. The testing was divided into two phases: compressed air and natural gas. These tests analyzed venting behaviors in various normal and abnormal conditions to determine safe clearance distances and reliable operation in the field.

Testing of the different configurations of FE25 regulators was performed in two parts:

Part1 - Compressed Air Testing

The first part of testing involved flow testing rig and follows ANSI B109.4’s design and test procedures as reference, using compressed air to simulate normal and abnormal operating conditions. The team conducted lockup tests (normal conditions), relief tests (normal conditions), diaphragm tear tests, and a lever disconnect test.

Part 2 – Natural Gas Testing

The outdoor portion of testing involved using live natural gas at 60-psig and a methane sensor array positioned at various distances from the regulator vent. Lockup and relief conditions were reproduced on the downstream piping to simulate realistic customer gas usage and measure the gas emissions

Methane sensor housing in a downward position.

from the regulator vent. A Software was then used to process this data to generate an approximate shape of the gas plume in the form of a graph.

Emissions were measured in the following conditions: Normal Conditions, during the Diaphragm Tear Tests, and during the lever disconnect test.

The newer Regulator, Calibrate Relief and No Relief models, remained below the explosive limit across all abnormal conditions. One advantage of this gas regulator over traditional IRV regulators tested in previous projects is that the OPSO engages when there is an abnormal operating condition such as a lever disconnect or a diaphragm tear. This was seen in all the abnormal operation tests conducted in this project. The highest LEL readings triggered the OPSO mechanism, stopping further emissions and preventing hazardous gas accumulation.

This project is complete. The final report on Testing of New Pietro Fiorentini Gas Service Regulators was released to OTD members in March 2025.

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OTD
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Evaluate Hydrogen Blend Measuring Devices

The objective of this project was to assess, evaluate, and compare the performance and effectiveness of various discrete non-GC hydrogen measuring devices for H2/NG blended gas distribution operations.

Project Description

As part of industry-wide decarbonization efforts, Local Distribution Companies (LDCs) are undertaking hydrogen blending projects to blend hydrogen gas into their natural gas distribution pipelines. An important parameter for LDCs to measure and monitor is the amount of hydrogen being blended into the natural gas pipeline. The project team researched the market to identify devices that detect and measure hydrogen blends in an inline-mounted pipeline application operating at distribution pressures. The team conducted testing to evaluate the performance of such devices and produced a report on the ability of these devices to replace Gas Chromatography (GC) technology in this application.

Deliverables

The deliverable for this project is a final report containing evaluation methods and recommendations for the GC alternative devices.

Benefits

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

Technical Concept & Approach

Specific tasks in this project included:

Identify Requirements

This task included working with project sponsors to define project requirements and performance parameters to be evaluated.

Technology Review & Acquire Devices

This task included researching the market for available devices and procuring the devices that meet the sponsors' requirements.

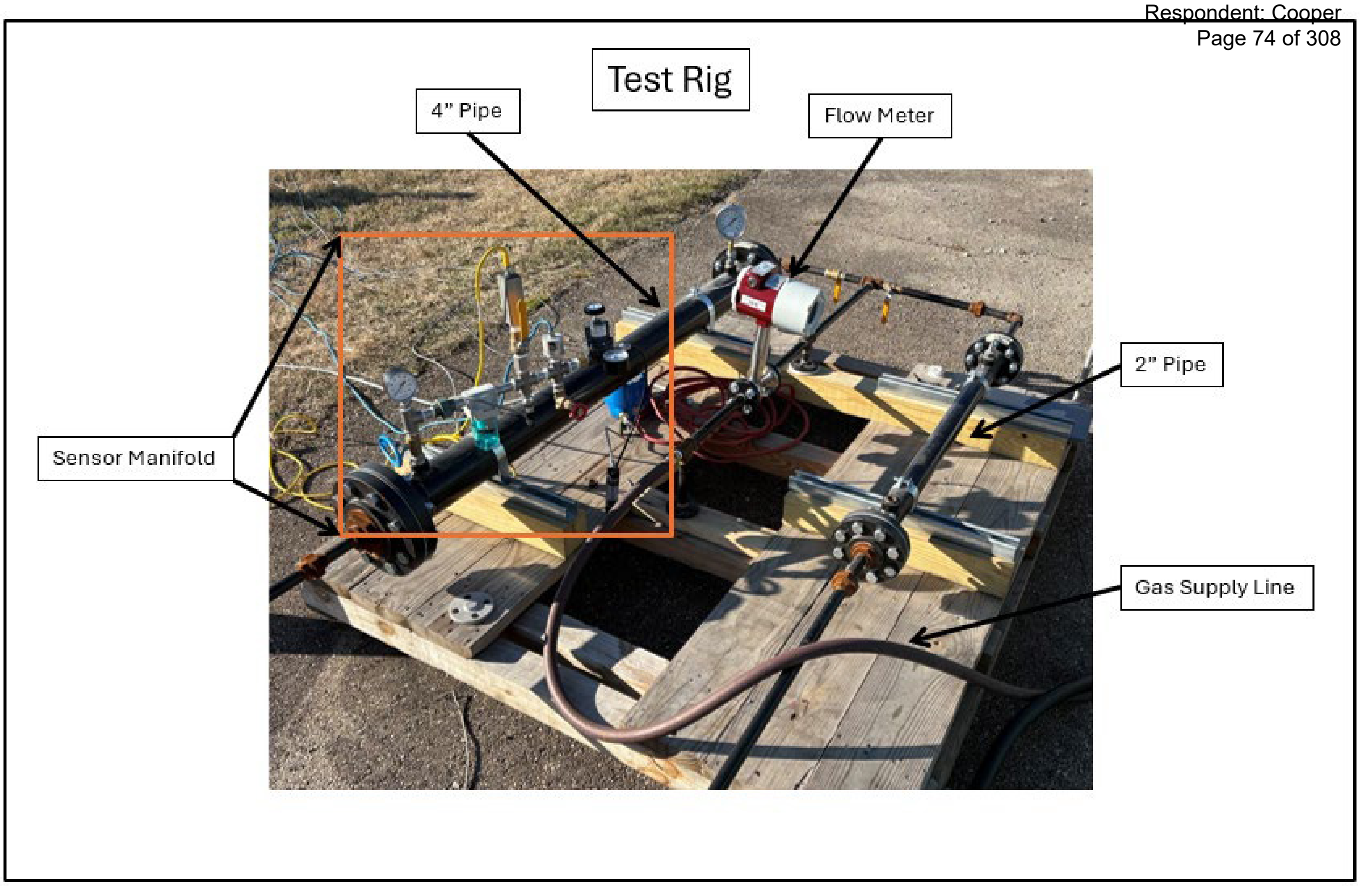
Lab Testing

This task included lab testing of the acquired devices.

Results/Status

For this project the team evaluated three commercially available hydrogen sensors: the BlueEye™ Ex-D by Bright Sensors, the HY-OPTIMA™ 5033 Series by H2Scan, and the gasQS Static by Mems AG in a simulated hydrogen-blend distribution pipeline.

The testing involved using these sensors with a simulated natural gas distribution pipeline environment. Tests were conducted using 2" and 4" steel pipes at 60 psig with a flow rate of 250-1000 cubic feet per hour. The test included switching between known and measured blends of natural gas including 0%, 5%, 10%, 15%, 20% and 25% hydrogen.



These sensors are being compared based on their ability to accurately detect and measure the mol percent of hydrogen in natural gas blends.

Two of the sensors were able to be directly connected to full pipeline pressure (60 psig) but one required low pressure and a relatively low flow rate to operate, so it had to be placed downstream of a pressure regulator and a flow control instrument.

Comparative performance time for the three systems varied, with the fasted being 2s and the slowest 5s. While the testing setup provided a simulated gas distribution line, it does not exactly replicate the field implementation of the sensors. The project team recommends expanding upon the current understanding of how hydrogen sensors can be implemented in distribution networks by developing hydrogen sensing stations that include the hydrogen sensors tested in this project.

The project team would also like to conduct further testing with these sensors to determine if more ideal operating conditions will improve accuracy.

To implement hydrogen sensors in distribution networks reliable hydrogen sensing stations will be required. Hydrogen sensing stations deployed in the field require additional supporting equipment including but not limited to a power source, energy storage, and potentially a pressure regulator. Testing the hydrogen sensing stations would require working alongside a gas operator to deploy the sensing stations in the field or a gas circulation system at the project team facility to evaluate the reliability and durability of the sensing stations.

This project is complete. The final report on Hydrogen Blend Measuring Devices was completed and released to OTD members in February 2025

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OTD Operations Technology Development

Remotely Deployed Double Balloon Stopper - Design Refinement

This project looks 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

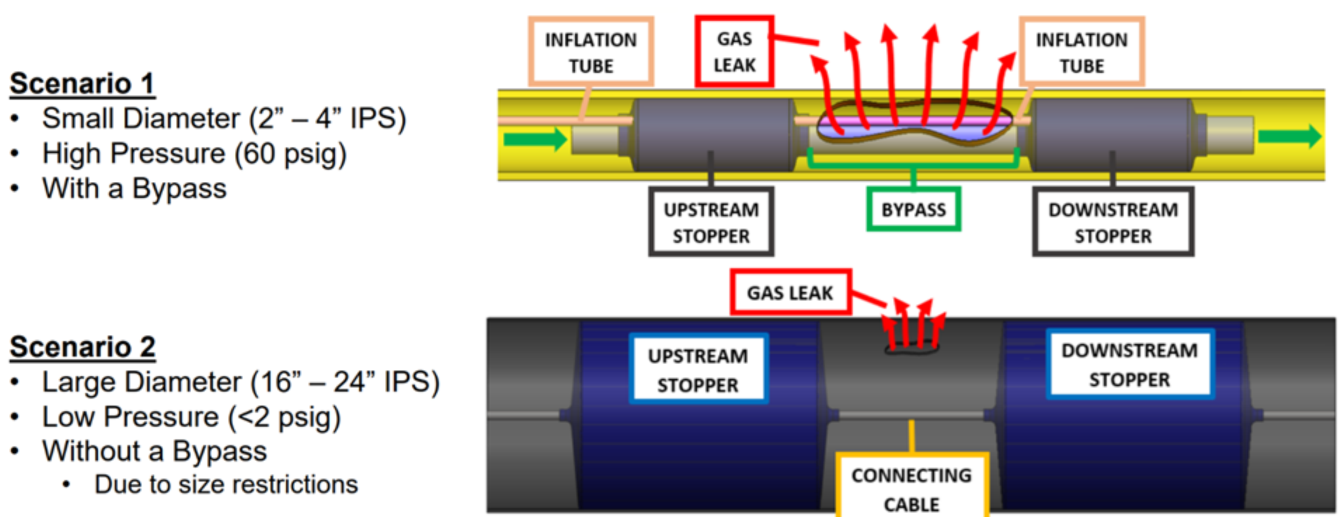
The deliverables for this project include: a fully tested, final prototype double balloon stopper, for small diameter (2" IPS - 4" IPS) – High Pressure (60 psig) systems (with a bypass); a fully tested final prototype double balloon stopper for large diameter (16" IPS - 24" IPS) – Low Pressure (<2psig) 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 will reduce the costs for the local distribution company (LDC) for having to access and stop the gas leak. Additionally, deploying this tool from a remote location 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.

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 two prototypes that the research team is developing and testing

The first application is to further develop the double balloon stopper prototype with a bypass for small diameter (2" IPS - 4" IPS) – high pressure systems (60psi), 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.

Results/Status

For the small diameter – high pressure (SDHP) system with a bypass, the project team worked with a mold manufacturer to create an injection molded balloon stopper that could be molded around an inflation line connector. The injection molded balloon stopper would be placed over a flexible bypass line that is reinforced by a spring on the outside of the bypass line. The inflation line connector would allow for the air to be transferred directly from the inflation lines inside the bypass line through the wall of the bypass line to fill the balloon stopper.

During testing of the small diameter injection molded balloon stopper, it was found that instead of inflating at the center of the balloon stopper as was expected, the injection molded balloon stopper inflated at the two ends. The project team has hypothesized that if the injection molded balloon stopper were to be lengthened, the middle section of the balloon stopper would be able to go across the entire gas leak and both sides of the leak would be able to be sealed by a single balloon stopper. The project team has proposed an extension project to be able to further develop and test this single balloon stopper which would be able to seal both sides of a remote gas leak without a second balloon stopper.

For the large diameter – low pressure (LDLP) system without a bypass, the project team developed two 24in canvas balloon stoppers which could be connected via a 36in long cable and inflated separately. They also created a Launch Tube Subassembly out of a set of 4in PVC Pipes which was used to successfully insert the connected 24in canvas balloon stoppers into a 24in steel pipe. However, when attempting to push the connected 24in canvas balloon stoppers down the 24in steel pipe, the balloon stoppers either got stuck or the connection/inflation rods got kinked or coiled.

The project team tested a variety of stiffeners of different materials, sizes, and wall thicknesses to find a combination that made it easier to push the balloon stoppers down the steel pipe while still being flexible enough to enter the 24in gas main from the 4in PVC launch tube. However, no stiffener tested was satisfactory to meet both requirements. The project team has hypothesized that instead of adding a strong enough stiffener to help the connected 24in canvas balloon stoppers move down the pipe, if the downstream balloon stopper was mostly inflated (70-90%) that the gas pressure would help push the connected balloon stoppers to move down the pipe. The project team has identified that an extension project would be needed to further develop and test the LDLP system using this deployment method.

A final report was submitted in Q4 2024 and a project extension to continue development of the SDHP prototype was proposed to OTD and has been approved and funded.

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OTD
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Development

Hydrogen Blending Program

The objective of this project is to address technical, knowledge and operational barriers to blending hydrogen in natural gas pipelines. The team will develop a clearinghouse website where links, documents, and other information and tools are compiled and can be accessed by OTD members

Project Description

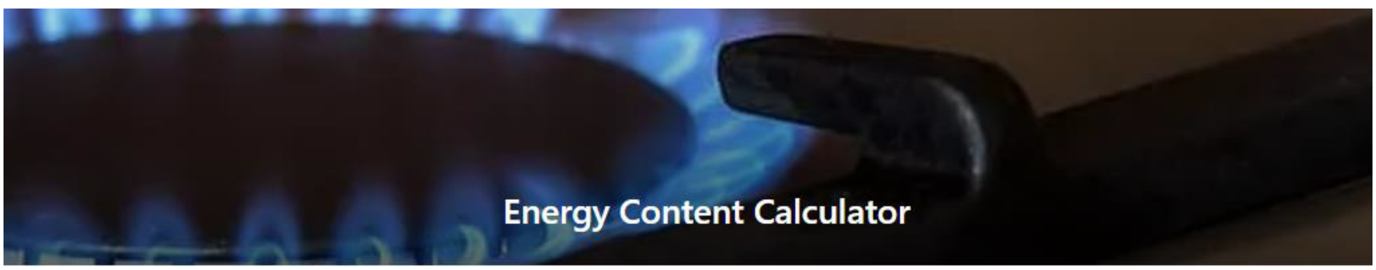
The goal of the Hydrogen Blending Program is to identify, collect, and share information to document the state of hydrogen blending in current natural gas piping systems. Key topical areas include materials compatibility, operational procedures, and safety considerations. The introduction of hydrogen in increasing quantities poses challenges for pipeline operators. They must evaluate the emissions benefits of higher H2 concentrations in existing infrastructure against the costs and risks associated with retrofitting the pipeline system.

Deliverables

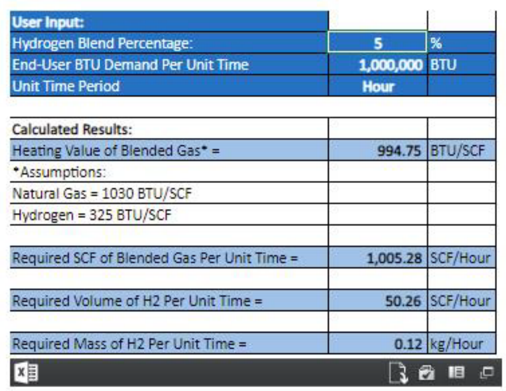
Deliverables of the program will be both a final report as well as a clearinghouse website where links, documents, and other information and tools are compiled and can be accessed by OTD members.

Benefits

This project 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, gain knowledge on how H2 can be safely and efficiently



The calculator on the right provides the heating value of methane-hydrogen blends, the SCF/day of blend required according to the end-user demand introduced and the required volume and mass of hydrogen required per day.



User Input:		
Hydrogen Blend Percentage:	5	%
End-User BTU Demand Per Unit Time	1,000,000	BTU
Unit Time Period	Hour	
Calculated Results:		
Heating Value of Blended Gas* =	994.75	BTU/SCF
*Assumptions:		
Natural Gas = 1030 BTU/SCF		
Hydrogen = 325 BTU/SCF		
Required SCF of Blended Gas Per Unit Time =	1,005.28	SCF/Hour
Required Volume of H2 Per Unit Time =	50.26	SCF/Hour
Required Mass of H2 Per Unit Time =	0.12	kg/Hour

Screenshot of Energy Calculator page

blended into current gas piping systems without harming the assets and equipment used to operate and maintain them, bring together industry experts to share knowledge, and provide information and resources to sponsors to allow them to make decisions on how to move forward with H2 blending efforts.

Technical Concept & Approach

The team will monitor and provide a summary list of different hydrogen projects conducted at GTI Energy, compile public findings from demonstration projects of hydrogen injection and/or blending in natural gas grids, track manufacturer declarations of equipment compatibility with hydrogen, and follow the development of standards for hydrogen compatibility in Europe, Canada, and the US.

Results/Status

The team developed the Hydrogen Injection Pilot Resources page. The Document Summary List includes 34 hydrogen-related GTI Energy projects which the team compiled. Each resource listing also includes a brief description of the document's content, which enables users to search the repository for specific keywords. The team also provided the link to the AGA's Hydrogen Activity Tracker which lists hydrogen projects and/or research in North America that is underway or completed, links to more than a dozen industry and academic research projects related to hydrogen compatibility with natural gas pipelines, materials, and standards, and hydrogen compatibility statements from two manufacturers of gas regulators and meters.

As the integration of hydrogen in natural gas infrastructure advances further, the project team expects that more standards and equipment testing for hydrogen compatibility will become available. The industry has made great strides during this project and will continue to do so in the future.

Work on this project wrapped up in Q4 2024 and the final report was released to OTD members in March 2025.

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OTD Operations Technology Development

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

Researchers tested 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 was 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 deliverable for this project was a final report that summarizes all the results and compares the performances of the different thread types. A cost analysis was also 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 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

All samples are connected to pressure transducers inside the temperature chamber.

materials. Fewer gas leaks also contribute to lower methane emissions.

Technical Concept & Approach

Specific tasks in this project include:

Identify Alternative Types of Threads

This task identified alternative types of threads and compared the dimensional tolerances in each thread type's respective standards. The team included NPTF and ANPT in this study to compare to general purpose NPT.

Fittings Testing

The work in this task included purchasing the fittings and measurement of the threads.

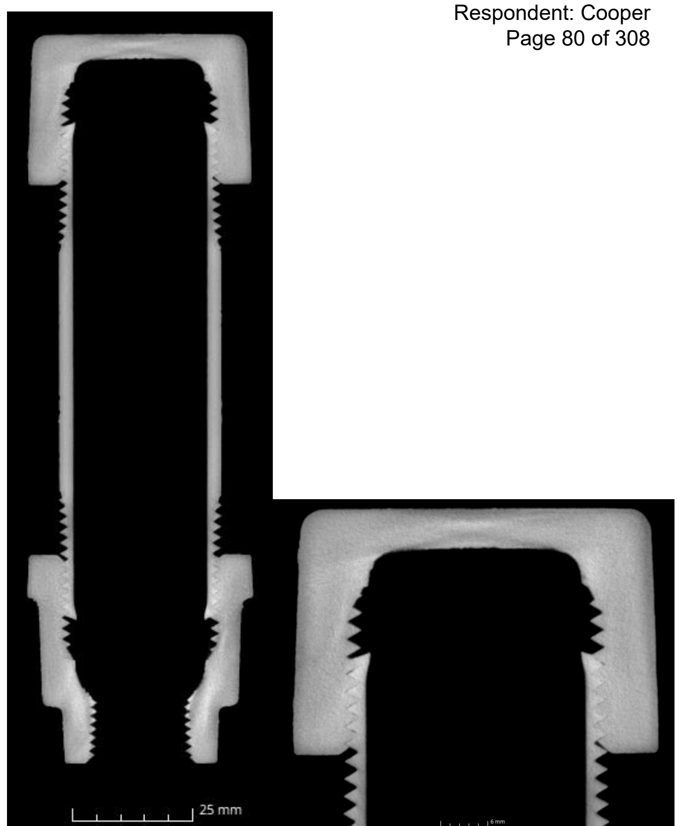
The work in this task also involved creating test samples with fittings of each thread type that passed dimensional inspection.

Results/Status

The project team compared the performance of different thread types in simulated field conditions. As a comparison between different thread types, sets of pipe samples were assembled according to their specific thread standards as follows: ASME B.1.20.1 NPT (National Pipe Thread) pipe samples, ASME B.1.20.3 NPTF (National Pipe Taper Fuel) fittings with thread sealant, and ASME B.1.20.3 NPTF thread fittings without thread sealant. To simulate the effect of thermal expansion in field applications, these pressurized pipe samples underwent a temperature cycling test while their internal pressures were data logged. Leak rates were calculated for samples that lost pressure during these temperature cycle tests.

One unexpected finding from this testing was that all NPTF Class 2 samples assembled without thread sealant were found to leak immediately once pressurized, even though the ASME B.1.20.3 standard states explicitly that thread sealant is not required for Class 2 since NPTF fittings rely on a "dry-sealing" method to achieve leak-tightness. Slightly more NPTF samples with thread sealant held their pressure than NPT threaded samples. However, this was not significant enough of a difference to recommend that NPTF Class 2 fittings are inherently more effective than NPT fittings.

NPTF threaded fittings Class 2 are used in critical applications with tighter tolerances where thread



CT scan of NPTF thread sample

sealant is undesired and are more commonly used in stainless steel or brass fittings. This study's findings indicate that NPTF threads may not be suited for fittings made of malleable materials due to their malleability and tendency for the NPTF threads to gall. However, more studies are needed to understand the performance of NPTF threads in malleable fittings compared to brass and stainless steel.

This project is complete. The final report on NPTF Threaded Fittings and Other Alternative Joint Connections for Meter Set Joints was completed in January 2025 and released to OTD members in February 2025.

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Operations
Technology
Development

Hydrogen Detection Tape Evaluation

The objective of this project was to assess the efficacy of various hydrogen detection tapes in identifying leaks under a range of environment conditions and across hydrogen leaks of differing sizes and compositions.

Project Description

The project team identified various hydrogen detection tapes on the market. Once identified, the technical team obtained the products and evaluated them under various hydrogen leaks (of various blends, pressures, and sizes) and in various environmental conditions (high temperature, low temperature, high humidity, weather resistance) and exposure to UV radiation and outdoor conditions. These tapes underwent a color change in the presence of hydrogen, which was permanently documented using time-lapse filming. This project aims to explore the feasibility of whether these products can help operators to detect leaking joints as they introduce hydrogen into their piping system.

Deliverables

Deliverables for this proposed research included identification of suitable products for quick and easy detection of hydrogen leaks and a final report.

Benefits

Hydrogen detection tapes offer a significant business value by providing a visual indication of hydrogen gas leaks, which conventional hand-held devices cannot easily locate. This visual detection method not only enhances safety measures, but also reduces the economic losses associated with shutdowns for leak repairs.

No Leak Detected

Hydrogen Leak Detected

Technical Concept & Approach

The primary task in this project was:

Testing and Evaluations

This task included evaluating the effectiveness of the hydrogen leak detection tapes by subjecting the tapes to live leaks of hydrogen-blended gas in various operating and environmental conditions.

Variables for hydrogen leak testing included: Hydrogen Blend Concentration (e.g. 10%, 20%, etc.);Hydrogen Leak Size (measured with flow meter at leak sample inlet) and pressures; Environmental Conditions (Different temperatures at 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 (UV radiation, corrosion, outdoor conditions, etc.).

The project team planned to use timelapse filming to provide illustrative demonstrations of the tape's color- changing process under different conditions, along with the period of time that passes during the color change.

Results/Status

The project team conducted an evaluation on the performance of tapes produced by two different manufacturers to effectively detect the presence of hydrogen leaks.

The performance and environmental testing confirmed the capability of both tapes to serve as a localized hydrogen gas indicator. Once exposed to hydrogen, the reaction in the tapes is permanent, necessitating tape replacement following leak repair. Under normal operating conditions, both tapes did not leave residue and were easily removed from applied surfaces. Residue was observed upon the removal of one tape after completion of the hot temperature test, although it was easily cleaned off with an organic solvent.

Transitioning to the performance distinctions between the two tape brands, the most notable difference lay in the reaction time and the clarity of the leak indication. Details of the results for both tapes can be found in the final report.

UV exposure test samples

During the long-term outdoor testing and the UV exposure testing, the degradation of the color-changing pigment in one of the tested tapes became apparent. Even the UV rays emitted from fluorescent lights within the laboratory were sufficient to degrade the color change, simulating the appearance of a non-reacted sample after several days. This issue of UV poisoning was not observed in the other tape.

This study confirms the viability of using hydrogen detection tapes as a practical solution for enhancing safety and operational efficiency in industries employing hydrogen gas. Their ability to provide quick and clear indications of leaks can significantly contribute to preventing economic loss, equipment damage, and safety hazards, thereby supporting the integration of hydrogen into the energy sector.

This project is complete. The final report on Hydrogen Detection Tape Evaluation was completed in March 2024 and released to OTD members in April 2024.

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OTD Operations Technology Development

H2 Steel Compatibility

The objective of this project is to establish the effects on material properties of pipeline steels when they are exposed to hydrogen.

Project Description

This project is to establish the effects on material properties of pipeline steels when they are exposed to hydrogen. An updated literature review with the latest results from efforts at GTI Energy and other entities will be performed. In-situ testing in a hydrogen environment will be performed for materials prioritized by sponsor companies. Validation testing of other materials may also be performed.

Deliverables

Deliverables of this project included an updated literature review, a database with material properties for all the samples tested, including the chemistry composition for those that were not fully characterized, a webinar to discuss the findings of the results and a final report that will include analysis of results, pipeline steel risk factors and potential impacts to engineering assessments.

Benefits

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

Technical Concept & Approach

Specific tasks in this project include:

Requirements and Literature Review Update

The team will update a review of current regulations and standards and the planned modifications for hydrogen injection (ASME B31.8, ASME B31.12, EIGA, IGEM, BS, CFR 192) and gather 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 will be reviewed.

Sample Gathering and Selection

The materials to be tested and the tests to be performed will be confirmed with the sponsors. The team has an extensive library of pipe samples although grade and chemistry information are unknown for many of them. Candidates with high probability of matching the targets chosen by the sponsors will be tested for chemistry. Additional samples from sponsors will be collected. A total of 10 materials will be 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 will be performed to confirm the grade. A maximum of three pipe samples per grade will be selected to perform tensile tests under hydrogen. Charpy baseline tests will be performed for characterization.

Tensile Tests in Hydrogen

The selected pipe samples will be machined to obtain additional tensile specimens. The samples will be tested hydrogen gas. This task will include 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 will be 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 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 will be described and quantified.

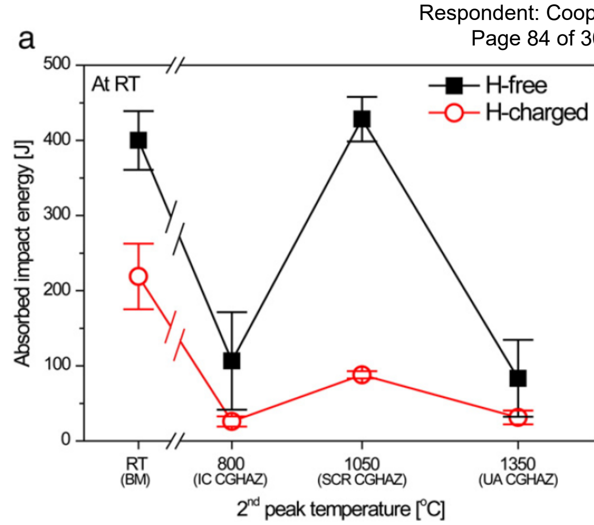
Results/Status

The project team reviewed methods for introducing hydrogen in steels to reach a concentration level that is representative of the hydrogen that would be introduced during operating conditions. Experimental results on the differences between gaseous charging and electrochemical charging were collected to design the best approach for hydrogen saturation of Charpy specimens. A total of 20 materials to be fully tested have been screened through chemistry analysis, and 10 samples were selected.

The sample selection criteria were: 1) specific samples of interest for operators, 2) samples with predicted low and acceptable or good toughness based on chemical composition, allowing comparison of the effects of hydrogen on dirty-clean steels, and 3) samples with characteristics that might correspond to high-risk steel when introducing hydrogen such as old installation date and thick pipe wall. The team also selected and ordered the Charpy tester that will be utilized for testing.

The project team performed hardness testing of the 10 pipe samples in accordance with ASTM E-18-22: Rockwell Hardness Standard Test Methods. Hardness scores were found to range from a low of 70 to a high of 96. The median hardness value was determined to be 81.

Additionally, the Charpy impact tester was assembled by the vendor and delivered to team, where the project team was trained in device usage. Machining vendors were solicited for fabrication of miniature Charpy V-notch (MCVN) specimens. Installation of ventilation enclosures and the related safety hardware components was completed for the Charpy Bay. Installation of tubing to connect the Charpy conditioning bath to the gas cylinders was initiated. The team investigated various autoclaves for subjecting specimens to pressurized hydrogen for conditioning and thermal pre-charging prior to testing.



The samples for tensile testing were prepared and sent to a vendor for machining. The machined samples were returned to team. Also, modifications to the hydrogen in-situ tensile test chamber were required as the original sight glass windows of the were found to be birefringent and thus incompatible with the video extensometer system. Furthermore, the grips developed for the chamber were tested with practice samples and found to have some slippage at the knurled gripping pads. Gripping pads redesign and fabrication was carried out and new parts fabricated.

The Charpy impact tester vendor will be onsite to deliver refresher training to existing team members and get new project resources familiar with the system and to perform the annual calibration of the machine. The project team will, also, perform a shakedown of the tensile testing chamber to validate proper performance prior to initiating testing. Additionally, efforts will continue on preparing the test equipment and rigs for testing by finishing tubing installation to support proper ventilation and installing metal sheeting on the wood beams above the Tinius Bay to prevent hydrogen pockets from forming. Tensile tests in hydrogen and Charpy tests with hydrogen conditioning are planned to be performed.

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OTD 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. This includes components such as valves, pressure regulators, gas meters, filters, seals, compressors and measurement equipment.

Since operators' systems all vary, an inventory of the equipment and components used by project members is necessary to understand the full range of operator needs. This project addressed 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

The project team gathered 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

The team identified a pool of suppliers with H2 ready products that could be used for demonstrator projects, assessing the interest of the suppliers on the development of this H2 ready equipment.

This included gathering included supplier information, type of technology, technological readiness level (TRL), main technical specifications (components, lifespan, reliability), operation procedures and utilities needed to operate equipment, maintenance procedures, norms and standards and certifications, and hydrogen ready technology roadmap (short- and mid-term).

Results/Status

The market study focused on Germany, the United Kingdom (UK), and the US. Components were filtered to identify H2 ready components that are specifically compatible with "pure" hydrogen gas streams, normally defined as hydrogen concentrations of 98% to 100%. In total, 79 H2 ready components are reported across the study regions.

For diaphragm, ultrasonic, turbine, orifice, rotary, and thermal mass meters, past studies suggest no significant measurement impacts with up to 20% hydrogen. However, increased leakage can lead to undermeasurements. There is inconclusive data on hydrogen impact on meter materials (e.g., sealants, adhesives, fasteners, lubricants). Long-term durability testing of materials is recommended to further evaluate impacts.

For leak sensors, electrochemical sensors used for carbon monoxide, oxygen, and hydrogen sulfide detection, hydrogen cross-sensitivity can lead to false positives or negatives. Thermal conductivity, catalytic, metal oxide semiconductor, flame ionization, and mass flow sensors can overread with hydrogen if the calibration gas was methane. Whereas infrared and etalon sensors would underreport flammable gas levels as these sensors are calibrated to methane.

For filters, vendor feedback suggests existing filters can accept 10 to 15 % hydrogen. It is recommended to use stainless steel filters for pure hydrogen applications. For current calorific value instruments used for natural gas applications, they were designed for pure hydrogen and would require replacement.

Below are a few conclusions separated by region.

European Original Equipment Manufacturer (OEMs):

OEMs in Europe that have supplied higher pressure components to industrial hydrogen gas facilities for decades have easily positioned their hydrogen compatible products for the emerging green and low-carbon hydrogen pilot projects and future potential.

Numerous European natural gas OEMs have customized natural gas components for medium and lower pressure hydrogen service. Ambitious commercialization and branding programs have positioned these OEMs to be prepared for the scaling up of hydrogen distribution, despite the uncertainties of the timeline and scale of conversion to hydrogen at medium and lower pressure networks.

European technical, standardization and certification bodies have facilitated the development of H2 Ready components. Online databases for H2 Ready components are growing. Some European OEMs have established in-house hydrogen testing and development centers.

North America OEMs and products sourced internationally:

H2 compatible components for higher pressure systems are readily available from North American and European OEMs. Selected American OEMs stated they do not currently offer H2 Ready valves but can do so on special order.

For medium and lower pressure distribution networks, H2 Ready availability is mainly for metallic components, such as pressure regulators, provided the OEM confirms that they meet US codes and standards. Conventional and electrofusion PE fittings are intrinsically hydrogen compatible, but OEMs generally will first qualify them for hydrogen use, as is customary in Europe. For specialized hydrogen compatible PE fittings, such as Excess Flow Valve (EFVs), these require prior testing and certification for hydrogen service. While H2 Ready EFVs are marketed in Europe, there are differences in dimensions (International Organization for Standardization (ISO) vs American Society for Testing and Materials (ASTM)) which may delay their availability for the North American market.

...

The literature review identified several additional gaps to hydrogen compatibility of existing equipment, such as odorization equipment, pumps, flow, temperature, and pressure sensors, heaters, valves, regulators, seals, and fittings. Compatibility will need to be verified with manufacturers.

This project is complete. The final report of Market Study of 100% H2 Compatible Distribution Equipment was completed and released to OTD members in September 2024.

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OTD Operations Technology Development

Screening Remote flow Monitoring and Control

The objective of this project is to perform a review of the technological state of the art on smart and remote equipment applied for distribution systems.

Project Description

The project performed a review of three primary areas of technology: 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. The need to monitor and control the blending of "green gas", such as Biogas, Renewable Natural Gas (RNG), or Hydrogen into existing gas distribution systems was the driver for this research.

The first step to putting these new capabilities into practice is to integrate into the network equipment that can gather data and react on command. The survey of equipment included in the scope of work for this project would allow the gas industry to have an up-to-date list of commercially available and emerging technologies, as well as identify any technical gaps between industry needs and market products.

Deliverables

Deliverables of this project included a review on remote flow control equipment, a webinar to discuss the results and any potential next steps, and a final report.

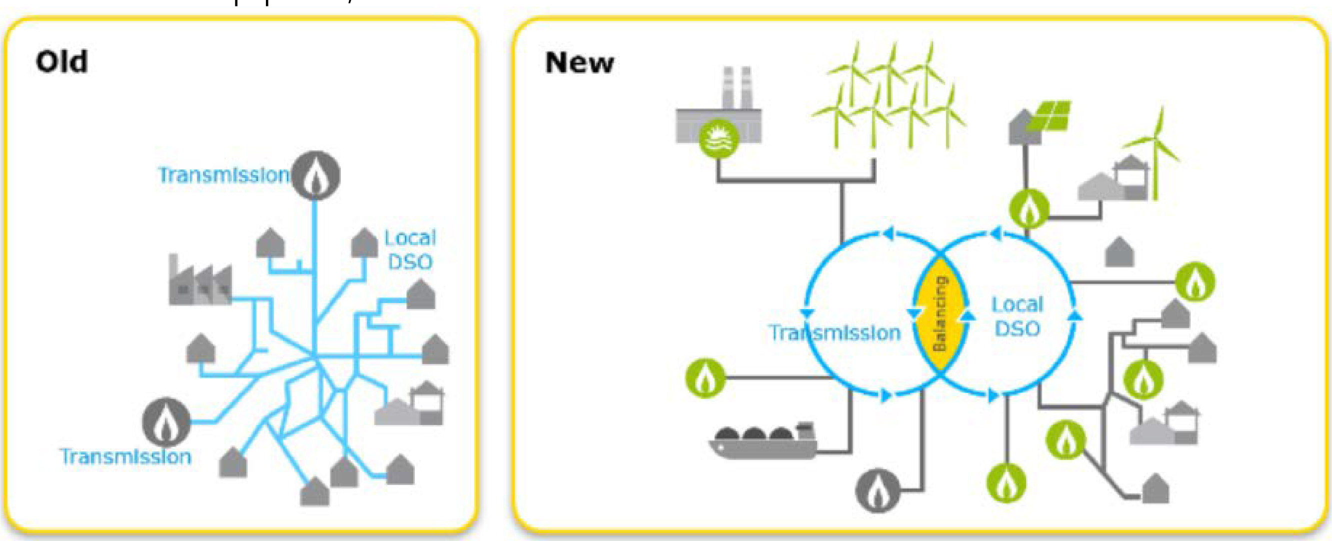
Benefits

The new technologies are needed to ensure the distribution system operation (DSO) can efficiently balance supply and demand. Smart and remote technologies will help optimize the use of diverse gas sources in the network, customer loads, and multiple sources. 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.

Technical Concept & Approach

Specific tasks in this project included:

Identification of Operator Requirements/Needs

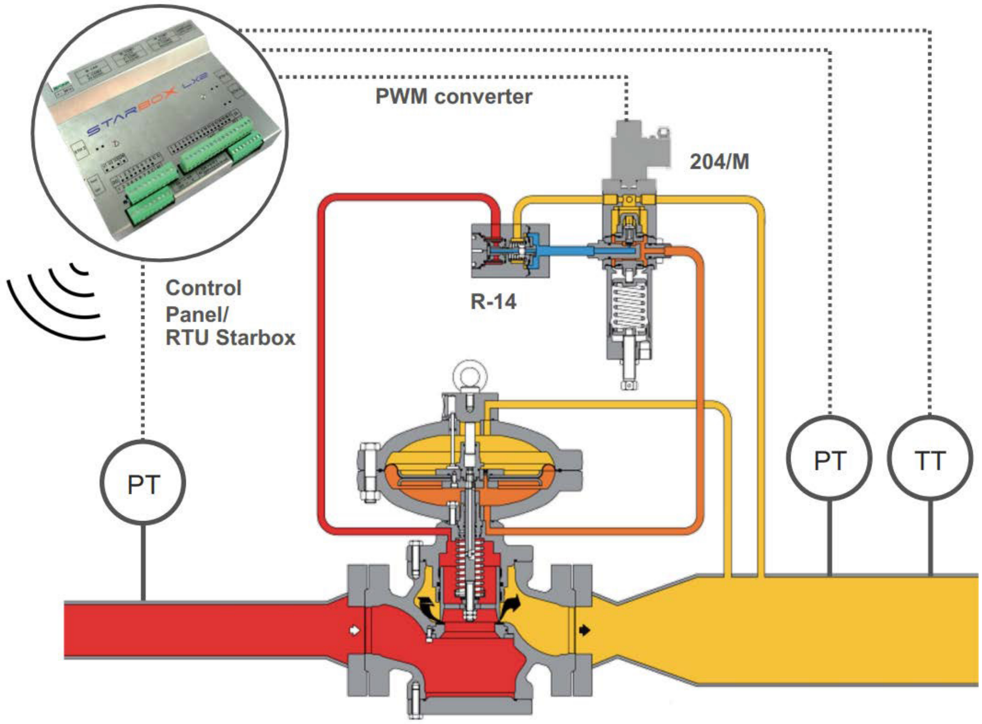


Increasing Sources of Gas Available to Local Distribution System Operators

The team held discussions/meetings regarding their current and desired components to meet future network infrastructure possibilities. The input and direction from the project sponsors also helped with the market study.

Market Study

The project team reviewed worldwide technological state of the art on the remote equipment and performed a complete screening of what is commercialized on the market and what is under development. The team also collected feedback on the use of these technologies from a technological and operational point of view, including operating and maintenance cost.



Schematic View of Typical Smart Regulator Installation

Results/Status

In execution of the project, the team first identified vendors working in these remote technologies for monitoring flow and composition of RNG or hydrogen into the system with on/off control of that flow. In general, the vendors in this space were unresponsive to requests for information. Most information in this report was found through web searches and publicly available documents.

Based on the research team's assessment, a subset of these companies appeared to have market-ready technologies, while others were under development. The research team surveyed suppliers regarding installation costs, product pricing, as well as operation and maintenance costs for products.

One sponsor from France currently has dairies producing RNG with direct injection into their grid, they are seeking a more standardized control package. The US sponsors had higher interest in managing hydrogen injection points because of differences in geographic areas, the US has less likelihood of having RNG sources located near an existing pipeline for direct injection than a smaller country. Utilization of green gas during the low-demand summer months is an issue that could be resolved by coordinating with gas-fired electric power generation. RNG production located close to gas-fired electric power generation will likely be limited.

In general, there are multiple vendors that can provide all the components for fully automated regulator stations that can analyze, monitor, and control the injection of gas into an existing distribution network. In practice, the utility wanting an automated regulator station would need to work extensively with the equipment vendor to define requirements and implement the system.

The potential future work in this effort would be a pilot scale project to set up and operate such a fully automated regulator system. The selection of the site would be critical. The proximity of the green gas source, existing gas pipelines, and gas-fired generation would be critical factors in a successful pilot demonstration.

This project is complete. The final report on Screening Remote Flow Monitoring and Control Technology was completed and released to OTD members in December 2024.

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OTD Operations Technology Development

Insertion Valve for Gas Mains

The objective of this project was to conduct an analysis and survey the current marketplace to identify existing technologies and equipment that could be options for safely stopping the flow of gas.

Project Description

Utilities are required to respond to gas events and elevated pressure gas main situations and resolve them effectively and efficiently. Frequently, response actions include line-stopping operations. Alternate technologies could aide in minimizing large system outages. The results of this project could yield another alternative to safely stop the flow of gas without impacting on the safety and reliability of gas distribution networks.

Deliverables

The deliverables for this project included a needs analysis describing the requirements of the project sponsors, a gap analysis highlighting discrepancies between sponsor requirements and current product offerings, and a final report summarizing project findings and how they may be applied by sponsors, discussed on a close-out webinar.

Benefits

In order to effectively respond to and mitigate the impacts of natural gas emergencies, utilities require tools that are flexible, quick to deploy, and easy to implement. Such line stopping solutions would promote more efficient shut down operations, thereby minimizing safety risk, reducing methane emissions and reducing costs.

Technical Concept & Approach

Specific tasks in this project included:

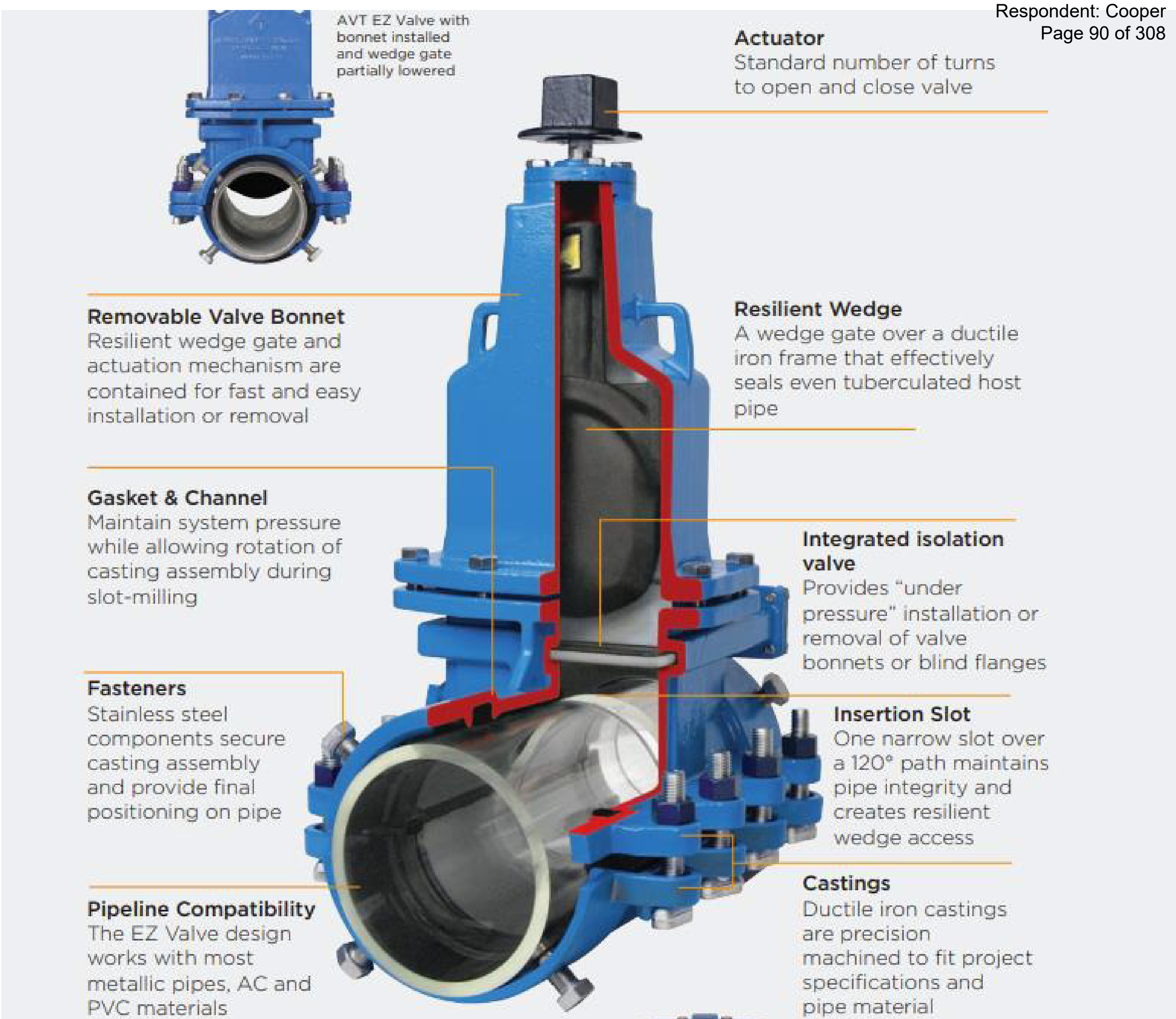
Determine Utility Requirements

In this task, the project team engaged with utility stakeholders to gather detailed requirements for the line-stopping solutions. This involved understanding the specific needs of gas utilities, including safety standards, operational constraints, and preferred functionalities. The insights gained ensured that the project would address the practical challenges utilities face in responding to gas emergencies and integrating new valve technologies into existing infrastructure.

Market Research

In this task, the project team conducted comprehensive market research to identify existing solutions and technologies in the line-stopping and insertion valve market. The research included analyzing competitors and reviewing technological advancements.

Insta-valve 250 (left) and Insta-valve 250 (right), (Hydra-Stop)



AVT EZ Valve (Advanced Valve Technologies)

Results/Status

The project team interviewed and held discussions with manufacturers about the potential for adapting an insertion valve from the water industry to the natural gas industry. After completing the market study, the project team identified that there is currently no existing insertion valve product in the market for the gas industry that meets utilities' needs: a tool that is flexible, quick to deploy, and easy to implement, leaving a significant gap for gas utilities.

The project team has identified a manufacturer that will collaborate on the development of an insertion valve for gas mains in a potential next phase of the project. The partnership between the manufacturer and the project team is set to advance the development of two 6-inch insertion valve prototypes, which will undergo rigorous testing to meet or exceed industry standards for performance and safety.

The plan will be to submit a proposal for the OTD to fund a phase two project for the development of an insertion valve for the natural gas industry. A comprehensive contract is being drafted to outline the project's scope, timeline, and deliverables, aiming to provide the natural gas industry with advancements for easily installing additional valves.

This project is complete. The final report was completed in September 2024 and released to OTD members in October 2024.

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OTD Operations Technology Development

Operational Data Through Connected Sensor Technology

The objective of this project was to identify and investigate available wireless sensors applicable to natural gas operations.

Project Description

Tracking the state of gas distribution infrastructure, and its contents, has become more critical as the complexity of our energy delivery systems increases. The gas and electric grids are becoming more intertwined and more in competition with one another. Operational and situational awareness resulting from timely data can maintain gas as a viable option in the face of these challenges.

This project aimed to identify and investigate currently available wireless sensors applicable to natural gas operations. The accompanying software and networks to aggregate and display the data was also surveyed. The focus was on categories of sensors that do not already have known gas industry implementations.

Deliverables

Deliverables of this project included a report that catalogues connected sensors that reasonably fit gas utility requirements and a summary and ranking of these sensors relative to selected KPI.

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 a lower cost than traditional SCADA systems.

Technical Concept & Approach

Specific tasks in this project included:

Survey of Available Sensors

The project team investigated sensor types including those types suggested by the sponsors. The search was limited to devices commercially available or in late stages of development. At a minimum, the following key performance indicators (KPI) were considered: Physical size, Battery life, Calibration longevity, Ruggedness/weather resistance, Connectivity options, and Price. A listing of identified sensors was compiled and ranked by these KPI. This information was reported out to the sponsors, promising devices were noted as candidates for testing.

Wi-SUN Alliance Engagement

The project team re-engaged with the Wi-SUN Alliance on gas industry needs. This organization promotes interoperability between wireless devices and establishes certification testing guidelines for this interoperability. The specific standard the Wi-SUN engages with is IEEE 802.15.4g. This is a hardware layer definition used in wireless mesh networking. The Wi-SUN Alliance goal was to enable the interoperable exchange of data between manufacturers using this standard. The goal of this project task investigation was to determine if various sensors can be Wi-SUN certified-interoperable across multiple AMI systems.

Results

The project team investigated devices in the following categories:

Water Sensing Devices

There are multiple categories of water presence sensors available that can be purchased already integrated with the wireless module. The sensors can also be acquired individually. Three main categories were identified:

Water Presence Rope: This is a water “rope” style sensor that changes impedance when the rope is exposed to water. The sensor does not provide a quantitative level for water, only presence or absence.

Ultrasonic Water Level: This is a LoRaWAN based sensor that can detect the level of fluid. This is an ultrasonic pitch/catch type sensor that provides the distance to a target; not limited to water. The device can be programmed to send messages when threshold distances (over or under) are crossed.

Water Float Switch: There are several float switches that are rated for use in hazardous locations. The safety rating of the switch is tied to the control circuit current. If the current through the switch is limited to intrinsically safe levels, then the entire system is intrinsically safe.

General Sensor to Radio Bridge

This category of wireless device accepts data from standard industrial sensors and provides a radio transmission of this data under defined conditions. These devices act as "bridges" between existing sensor types and a wireless protocol.

Dry Contact Sensor Bridge: The two-wire dry contact sensor detects a connection between two wires and transmits a message when there is a change. The weather-proof enclosure makes the sensor suitable for outdoor and industrial use. The form factor is identical to the 4-20 mA device discussed below. An existing sensor type, such as a float switch, can be adapted to wireless use.

Thermocouple Bridge: This is a LoRaWAN based sensor from Radio Bridge that can capture and transmit temperature readings from a type K thermocouple. The device can optionally be configured for other thermocouple types. Readings can be transmitted both periodically and on threshold crossings.

General 4-20 mA Bridge: This is a LoRaWAN based sensor from Radio Bridge that will capture and transmit readings from a 4-20 mA type sensor. The device can be programmed to send messages when threshold readings (over or under) are crossed. This could be useful to adapt an existing sensor type for remote reading. The caveat with this device is that the loop power must be provided externally, not from the transmitter battery.

Intrusion or Presence Detection

These are devices that can detect when an area has been entered or motion is detected and transmit a signal.

Passive Infrared (PIR) Presence Detection: The device incorporates a PIR detector in the same housing with multiple sensors and the LoRaWAN radio. The device has the PIR sensor packaged as a probe that can be located remotely from the main body of the device. Both devices also include temperature and humidity sensors.

Vibration Detection: These are devices to detect motion or vibration in facilities and equipment. Changes or increases in vibration can indicate tampering or the need for maintenance. This application is challenging in terms of battery power management. The output provided can include root mean square (RMS) velocity and acceleration, peak displacement, standard deviation, and other variables. The device can operate for up to two years between battery changes based on a once per hour transmission of data. As with other devices reviewed, the periodic transmission rate and the alarm transmission thresholds are adjustable.

The prevalent connectivity options are LoRaWAN or LTE-M1. These have different design constraints and present a buy versus lease option for capturing data. LoRaWAN requires gateways to capture the wireless data and forward it to the utility. The utility will need to procure and set up gateways, so this option becomes attractive if there are multiple sensors near a gateway. There are some areas in the US that have public LoRaWAN coverage that will forward data on a fee per message basis. LTE-M1 is available in most areas with cellular coverage. LTE-M1 data traffic is billed per message plus a monthly base fee per device. LTE-M1 may be the better option for single sensors that are in remote locations.

Effort was also expended to engage with the Wi-SUN Alliance. This group promotes interoperability testing for devices using the IEEE 801.15.4g wireless communication protocol. This is a mesh networking protocol that is used by major AMI manufacturers. If interoperability can be achieved in this space, current proprietary implementations of 801.15.4g may become open to the point where sensors from multiple vendors can co-exist with legacy AMI systems.

The finding is that the Wi-SUN Alliance has made progress certifying interoperable electric metering infrastructure components. None are battery operated. Developing a product for electric metering has fewer constraints than for gas. There has not been the same progress with gas metering. There is also no Wi-SUN certified communication device that is battery powered; this would be a foundational item for gas applications.

This project is complete. The final report on Operational Data through Connected Sensor Technology was completed and released to OTD members in January 2025.

For more information:

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OTD Operations Technology Development

Best Purging Practices for Minimizing Methane Emissions

The objective of this project was to establish best purging practices for the elimination or avoidance of methane emissions during pipeline construction, commissioning, and maintenance.

Project Description

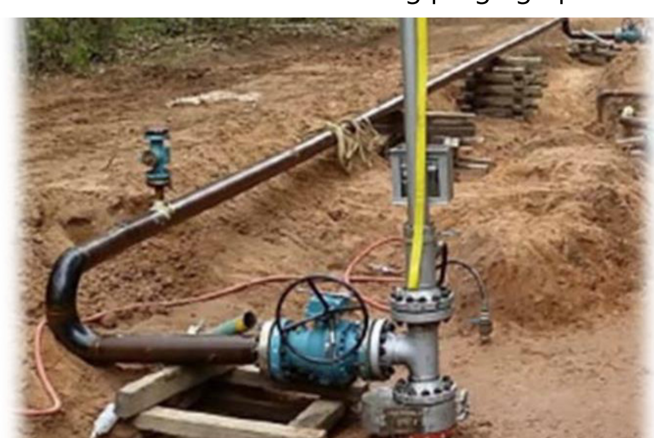
The natural gas industry is making great efforts to curb carbon emissions and operators are setting internal company goals to reduce and/or eliminate methane emissions from day-to-day operations of their natural gas systems. The energy sector has become more conscious about the release of greenhouse 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. Logistically, simply venting gas is typically going to be the most time-efficient method of purging a pipeline. However, ideal alternatives to venting will provide an economic incentive to the operator, while also saving time, resources, and addressing environmental concerns.

Deliverables

Deliverables of this project included the formation of a technical advisory panel, conducting interviews with equipment providers, conducting a comprehensive literature survey, a technology survey, and publishing a final report.

Benefits

Alternatives to blowdown during purging operations provide an opportunity to reduce methane emissions that would have otherwise been vented and can save a potentially large volume of natural gas from being wasted. The avoidance of methane emissions from blowdown/purging operations has both economic and environmental advantages. 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.



A below-ground pipeline section that has been isolated using stopples and an above-ground bypass line to avoid service interruption to customers

Technical Concept & Approach

Specific tasks in this project include:

Literature and Research Review

The literature review will include a survey of alternative purging methods and techniques as described in prior research materials, as well as examples of how these technologies can be applied to different purging operation scenarios. In addition, the project team interviewed various natural gas operators and equipment manufacturers to identify best practices and equipment used to minimize and/or eliminate methane emissions when purging pipelines.

Examination of Alternative Purging Methods:

The project team provided detailed information about the operational procedures and challenges associated with each identified purging alternative. Examinations of the purge alternatives included the estimated time required to perform the operation based on standard purging practices based on pipeline size and volume of gas. In addition, an economic analysis was conducted to compare the operation costs, time costs, and costs of the natural gas being saved from purging, comparing the alternative practices to current practices.

Purging Best Practices and Recommendations

The team compiled the attributes of the identified strategies and methods to reduce, eliminate, or avoid methane emissions during purging operations and provided recommended best practices for their applications in different purging scenarios.

These recommendations were defined best practices used by natural gas operators seeking to implement some of the identified alternative methods for purge operations.

Knowledge Transfer

This task included reviewing findings from the previous tasks with project sponsors and contributors to best determine the feasibility of implementing alternative purging methods, as compared to the methods currently used in the natural gas industry.

Results/Status

The purging alternatives identified and described in this project were gathered through communications and feedback with the project's Technical Advisory Panel (TAP) members. Commonly mentioned challenges were related to the cost, time required, customer impact, and added logistics of planning how compression equipment is to be transported to the worksite. The project interviews have indicated that gas operators are just starting to use purging alternatives, and that more industry technology is needed to completely prevent purging into the atmosphere.

The following methods to avoid venting to the atmosphere were considered:

Reduction of Line Pressure Prior to Purging

When an isolated volume of natural gas needs to be evacuated from a pipeline section, actions can be taken to reduce the amount of gas remaining in the isolated section of pipe prior to implementing the blowdown operation. Often this is done through customer usage to draw down the pressure and reduce the gas volume.

Cross-Compression

A cross-compression system recovers the gas that would have been vented to the atmosphere by compressing the gas in the isolated section of pipe and transferring it to a different section of the pipeline, another nearby pipeline, or storage location.

Flaring

The purpose of flaring as a purging alternative is to combust natural gas instead of releasing it to the atmosphere. Combusted methane does still emit a volume of CO_2 to the atmosphere, but this emission has much less global warming potential than venting methane. Flaring in an urban area setting can cause public concern, the non-combusted natural gas will exit the flare, and can drift downwind, and may cause an increase in odor calls.

Enclosed Combustion

An alternative to flaring that produces no visible flame. These units sometimes employ methods of thermal oxidation that allow for a more efficient combustion of the blowdown gas compared to burning the gas on an open flare stack. The operation of this equipment does not produce a noticeable flame, odor, or extreme external heat to the environment.

Vacuum Purging

Vacuum purging is a novel method which eliminates the need to vent natural gas to the atmosphere when a new or repair gas pipe is purged into service. By removing all air from the pipeline with the vacuum system, natural gas is not required to push the air (or inert gas such as nitrogen) out of the pipeline and the venting of this air/gas mixture to atmosphere is nearly eliminated. The project team has previously developed and evaluated a vacuum purging system to be used to purge pipelines into service. The vacuum purging systems were demonstrated successfully.

Implementation Feasibility of Different Purging Alternatives

The most common challenge cited by survey respondents and interviewees was the amount of time required for performing alternative purging operations as compared to venting the gas into the atmosphere.

The use of a purging calculator to track methane emissions is needed. These types of tools account for pipe diameter, operation pressure, and pipe length to calculate the mitigated emissions and offer ways for gas operators to track reduction goals and improve over time. Many interviewed operators also have emissions mitigation tracking tools, but do not currently account for the emissions related to transporting the equipment to the jobsite. This may be a factor that can be included in future iterations of these tools

This project is complete. The final report on Best Purging Practices for Minimizing Methane Emissions was completed and released to OTD members in April 2024.

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Kleiss Stopper Increased Pressure Enhancements & Evaluations

The objective of this project is to advance the development and evaluation of the Kleiss stopping system to support higher pressures.

Project Description

The introduction of the high pressure rated stopping system will supply pipeline operators with another option for continued, more efficient operations within their systems. The project team will work with Kleiss and their North American distributor Mainline Control Systems (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.

Deliverables

Deliverables of this project include: a questionnaire and benefits analysis, a requirements definition and gap analysis, a final system design, a system testing document, test results of a new prototype, a tested, increased pressure stopping system with updated flow stopping towers and MDS stoppers, and a Final Report and project closeout webinar.

Benefits

Increasing the operating pressure will allow utility companies to expand their uses of the flow stopping systems for most pressurized pipe applications.

Technical Concept & Approach

Specific tasks in this project include:

Analysis and Requirements Definition

The project team will work with the project sponsors to understand their needs and desired 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. The project team will distribute an electronic survey to sponsors as a means of collecting, recording, and prioritizing the customer needs. 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 electronic survey results will be used to extract a set of increased pressure stopping system requirements. A Requirements Definition document will be produced and reviewed with the project sponsors to validate accuracy and completeness. The team will facilitate a complete survey of the current Kleiss product offerings to identify those that most

Kleiss stopper system controlling system flow on PE piping systems

Kleiss MDS stopper

Kleiss MCS60-38 Stopping System

closely match the sponsors' needs. The findings, including an analysis of gaps between sponsor requirements and current Kleiss offerings, will be documented.

System Design and Development

The project team will work 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. Upon acceptance of a final design by all stakeholders, Kleiss will focus on manufacturing the increased pressure rated system. Additionally, Kleiss will perform regression testing to be certain any newly upgraded capabilities have not compromised the functionality of existing features.

System Testing

The project team will conduct testing of the newly developed increased pressure rated system. A system testing document will be developed which identifies use case scenarios and defines a testing matrix. Testing results will be reported to all project parties and needed modifications will be prioritized by severity of operational impact.

Results/Status

The team developed a framework for capturing, adding, tracking, and integrating requirements for upgrading the MCS 60-38 system to the MCS 120-38 system. The resulting requirements matrix was reviewed by the project team, MCS, and Kleiss prior to formally sharing it with Sponsors. Failure Mode and Effect Analysis documents were drafted for the tapping and flow stopping processes that identify items such as what process step failure looks like; the effect, severity, and cause; and detection and correction actions.

Required edits to the gear box of the MCS 120-38 system were considered and an initial version of a diagram was produced by Kleiss. The team worked on identifying a supplier of the PE fitting with a 3″ tower (2.5″ bore) after the original supplier indicated they could no longer produce the item. Drawings for the pipe cutout tool were completed.

Kleiss moved forward with PE electrofusion fitting development and identified a manufacturer to produce prototype fittings for the 6″ and 8″ stoppers. Kleiss is working with the manufacturer to finalize the initial order details. Additionally, the simple gearbox used for the lower pressure system was replaced by an air-driven gearbox and the Tower design for the higher-pressure system was completed.

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OTD
Operations
Technology
Development

Plastic Gas Pipe Damage Assessment due to high pressure water jets and cross bores

The objective of this project is to develop a set of guidelines to ensure safe use of water jetting when there is a risk of a plastic gas pipe cross bore in a sewer.

Project Description

The project team will perform an evaluation of the effect of high-pressure water nozzles from the sewer cleaning industry on PE cross-bores. This will involve working with industry leaders to identify multiple water nozzles used in the sewer industry, constructing a testing rig, and working with industry leaders with the intent to develop a set of guidelines which could be used by the sewer cleaning industry to improve natural gas safety when clearing sewer lines with water nozzles when there is a potential cross-bore.

Deliverables

The deliverable for this project is a final report detailing the project and project results of the high-pressure water nozzle testing.

Benefits

The development of guidelines for operating sewer cleaning nozzles around cross-bores, and testing standards for qualifying these sewer cleaning nozzles, will improve natural gas safety and integrity. It will reduce the risk of potential emergencies and catastrophic incidents and avoid the associated costs. Ruptured cross-bores can create hazardous conditions for homeowners through the unexpected entry of natural gas into a house through the sewer line. This research will help save the cost of repairing damaged homes and has the potential to save lives due to a leaking cross-bore.

Gas Cross-Bore through a Sewer Line

Technical Concept & Approach

Specific tasks in this project include:

Review of Standards and Market Research

This task involves reviewing the relevant standards in the sewer industry. The team will identify and procure high-pressure water nozzles for testing and develop a test plan to be approved by the project sponsors.

Development of Test Rig

This task involves designing and constructing a test rig based on the test rig built by the University of Waterloo, adapted to simulate a cross-bore through a sewer line. The vision is that this test rig will be available for future testing as other water jet nozzles become available on the market.

Blockage caused by Cross-Bore in Sewer Line

Plumbing Auger about to cut through Cross-Bore

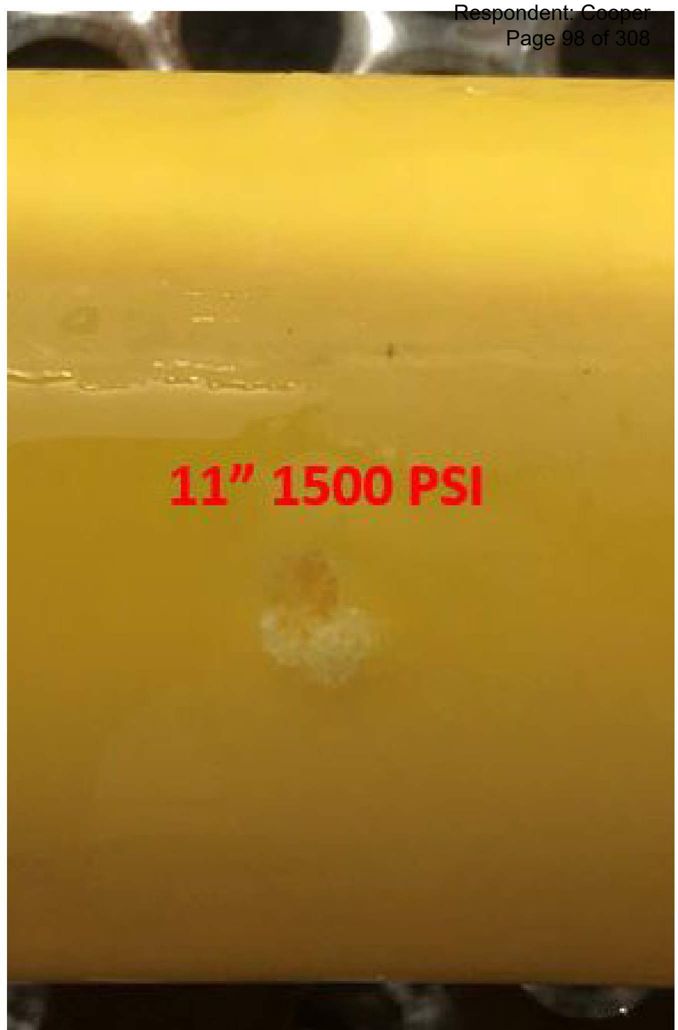
Testing of High-Pressure Water Nozzles

This task involves the testing of multiple high-pressure spinning and straight jet water nozzles on MDPE pipe. The variables tested will be the nozzle style, nozzle brand, and distance from the pipe.

Results/Status

The project team began developing a test plan and an initial test rig design. The team held an update meeting with the project sponsors and determined that a significant redesign of the test rig was needed. The test rig needed to accommodate sewer cleaning nozzles with side-facing jets and the necessary associated movement away from the test pipe in a perpendicular direction. It also needed to relocate the test pipe to be located below the sewer cleaning nozzles, such that powerful sewer cleaning nozzles with downward-angled rear-facing jets could be properly evaluated. Additionally, the method of supporting the sewer cleaning nozzles needed to be redeveloped to accommodate these two nozzle styles, as well as the size and weight of the larger sewer cleaning nozzles identified during the market research.

The team redesigned the test rig to accommodate these changes and subsequently completed the assembly of the testing rig. Additionally, the project team has finished troubleshooting the vertical



MDPE Pipe Punctured by 1500psi Straight Tip Water Nozzle at Height of 11in after 12sec

movement of the horizontal rails and nozzle carriages such that it can be operated with two individuals using linear air springs. Additionally, the electrical data acquisition system was installed such that the entire test rig is ready for testing. Testing is expected to complete in Q1 of 2025.

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

The objective of this project is to demonstrate the feasibility of large-scale Underground Hydrogen Storage (UHS) in porous rock formation through bench-scale experiments and field-scale dynamic reservoir simulations.

Project Description

The project aims to develop a framework that helps the industry with identifying suitable underground hydrogen storage sites as well as recommendations for controlling and monitoring H2 movement and loss within the UHS reservoir. The project will focus on conducting lab experiments and reservoir modeling to develop site screening criteria.

Deliverables

Deliverables of this project include evaluate potential underground H2 storage, guidelines and recommendations on safety and regulatory issues, and a final report.

Benefits

Develop a set of guidelines to assess the suitability of porous rock UHS sites. Conduct a detailed review of the API underground natural gas storage standards and incorporate them into the framework. Establish operational considerations for preventative or mitigative measures to reduce H2 gas loss and best practices to monitor H2 gas loss within the storage boundaries.

Technical Concept & Approach

Specific tasks in this project include:

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

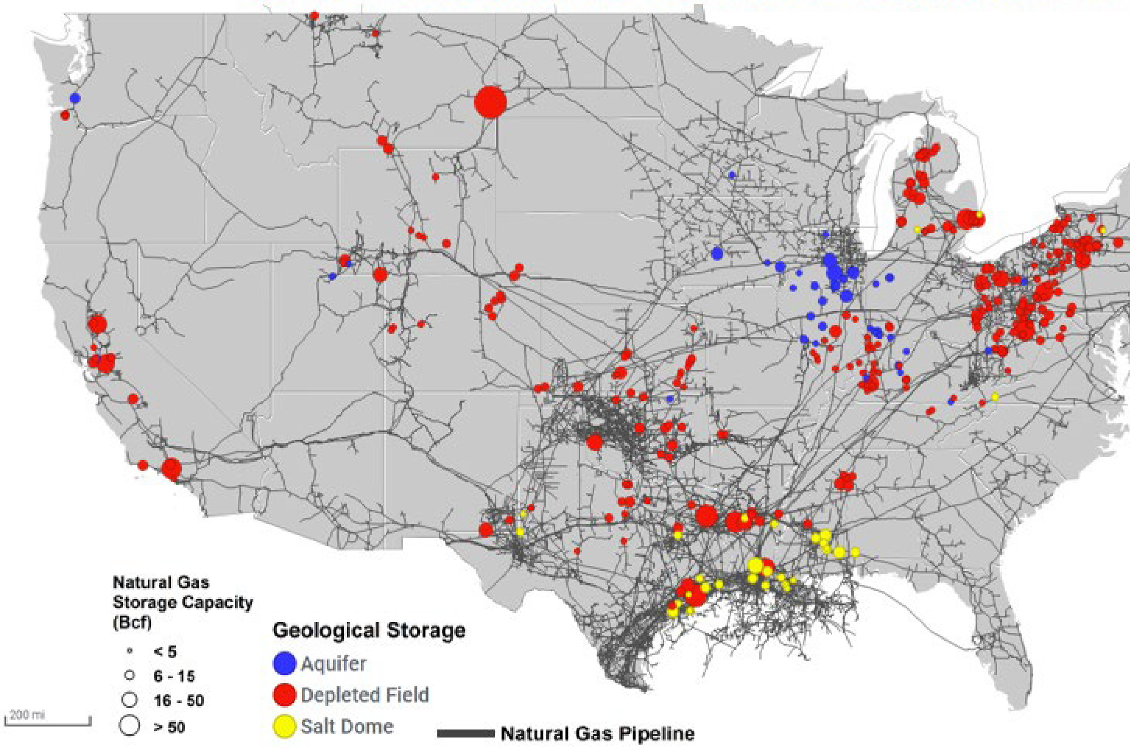
Develop a set of guidelines to assess the suitability of porous rock UHS in aquifers. Incorporate the American Petroleum Institute (API) underground natural gas storage standards, operational considerations for preventative or mitigative measures to reduce HS gas loss, and best practices to monitor H2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

Results/Status

The initial evaluation of petrophysical and structural characteristics is fundamental in assessing a site's suitability for hydrogen storage. This includes parameters such as porosity, permeability, geomechanical stability, and depth of the formation. While comprehensive criteria for selecting UHS sites are still evolving, certain generalized guidelines have been identified in the literature, these include: Ensuring the absence of geological faults compromising the target structure; Adequate thickness and depth of the geological structure to support required flow-back pressure ranges; Presence of an effective seal not compromised by surface or subsurface infrastructure; Absence of minerals prone to react with hydrogen, such as carbonates, sulfates, sulfides, and Fe3+-oxides; Permeability exceeding 0.1 mD without requiring stimulation, and transmissivity exceeding 100 mD.m within the reservoir; Data from gas storage sites and depleted gas fields indicating minimal presence of H2S (<10,000 ppm); Preferably, a Gas Initial In Place (GIIP) volume below 30 billion cubic meters to minimize cushion gas requirements.

This preliminary study indicates that the sandstone/shale brine aquifer within the Illinois Basin demonstrates the capacity and injectivity necessary for supporting subsurface hydrogen storage and fill/drain cycles. The presence of interbedded shale and shale caprock above the targeted injection

US natural gas pipeline and underground storage sites



interval serves as a barrier, effectively limiting the dispersion of H2 in the subsurface and resulting in elevated gas saturations near perforations.

It also suggests that the horizontal injection through lateral drilling in targeted sandstone reservoirs is shown to maintain higher gas saturations near the wellbore compared to vertical perforation placement in a conventional vertical wellbore setup. Dynamic reservoir simulation also indicates that horizontal injection of H2 leads to a sequential decrease in water production over 10-60 daily fill/drain cycles, preserving both cushion gas and working gas pressure near the wellbore. Conversely, vertical injection results in a sequential increase in water production and reduction of pressure. The management of associated brine production during the drainage of stored H2 can be achieved by adjusting the volume of cushion gas and the length of perforations in the targeted reservoir. Maximizing injectivity/drainage with the fewest open perforations is crucial for controlling brine production effectively.

It is important to note that there are still open questions that must be resolved spanning from basic knowledge of the physical properties to site-specific questions on hydrogen movement and potential loss. These include questions related to the caprock sealing and containment, biogeochemical reactions, multiphase flow of hydrogen with formation fluids, and the impacts of repeated injection-reproduction cycles on the stress field and geomechanical integrity of the reservoir.

The final report will include all the generated data on Ironton/Galesville's index, flow, and poromechanical properties. The indirect measurements of multiphase flow properties (coming from the pore structure-based estimation approach) will be compared to the direct measurements for the reservoir specimens. The hydrogen breakthrough and flow properties for the caprock representatives in the Ironton/Galesville formation will be analyzed based on the indirect approach.

Integration of hysteresis into both caprock and reservoir is ongoing. This requires the transfer of the model into the Software. Work continues with H2 injection experiments in the caprock (shale) to evaluate any mineral and/or pore changes after the core samples are subjected to H2 injection SEM coupled with an EDS and analyze the experimental results of H2 dispersion in cores.

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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. Natural gas operators are familiar with the hazards of natural gas but are not as familiar with the hazards of hydrogen. 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 was to simulate a pipeline leak and understand the potential risks associated from this event. In this project, the outcomes for 100% hydrogen pipelines and blended hydrogen/natural gas pipelines are compared to 100% methane gas pipelines (as a proxy for natural gas) to assess impact to risk.

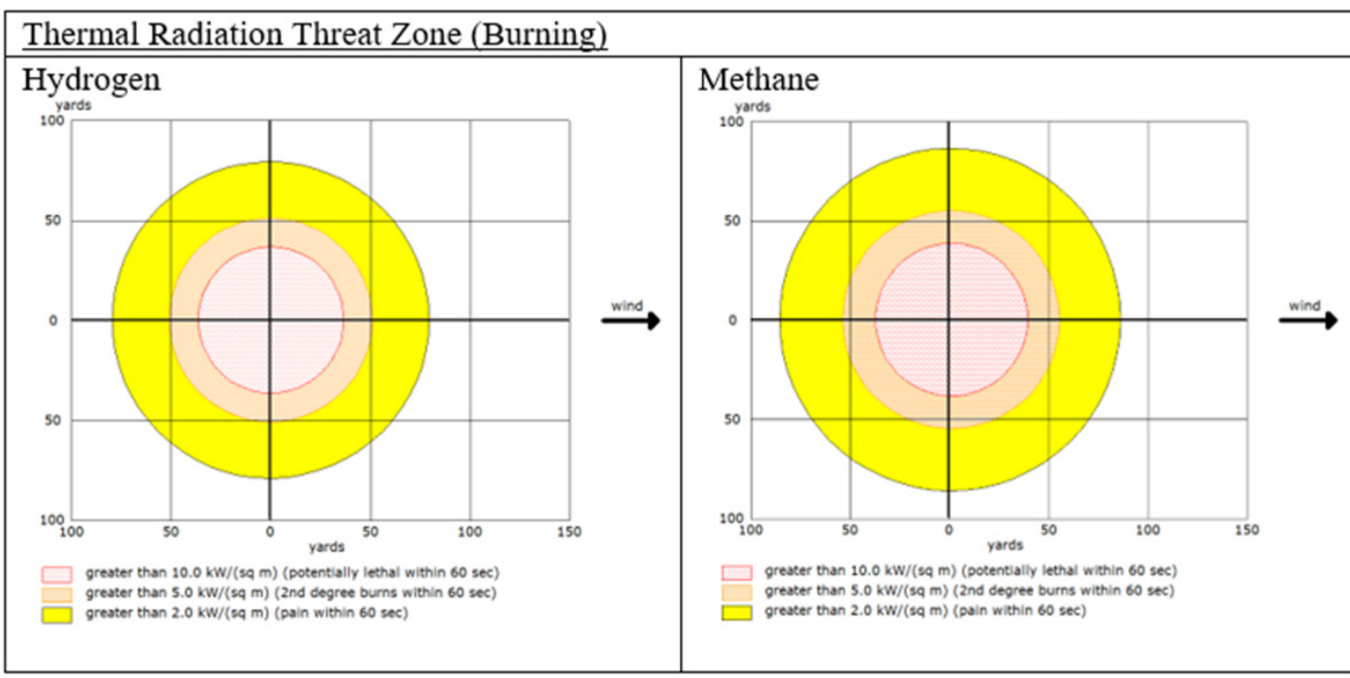
Deliverables

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

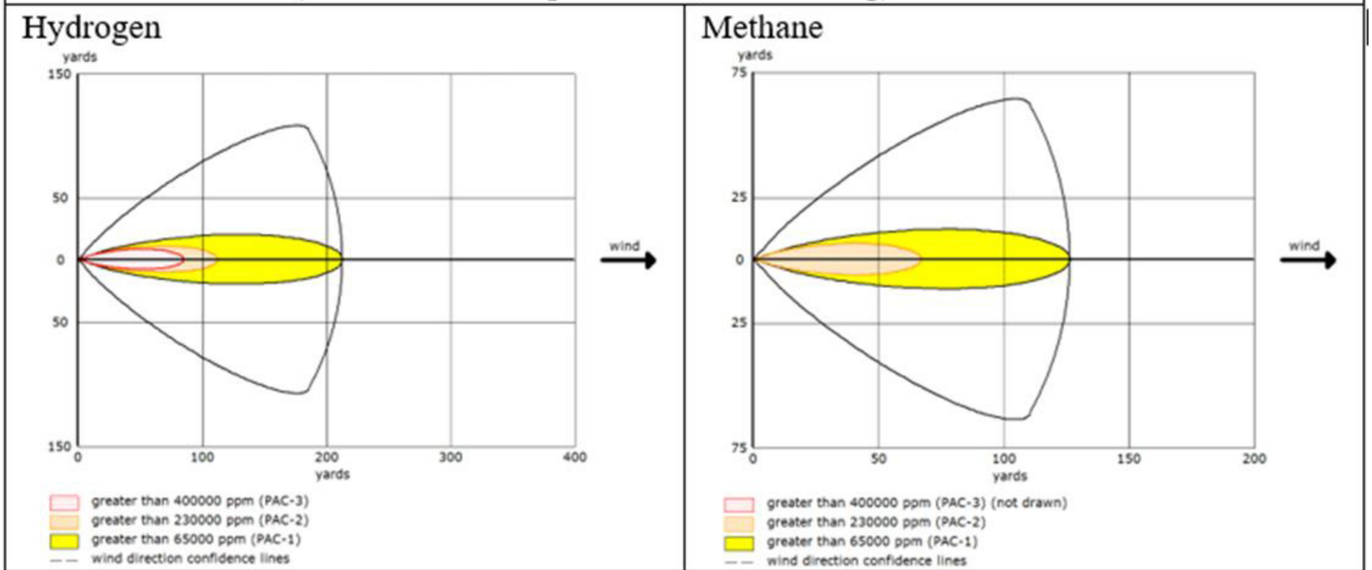
Benefits

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 carried out pipeline hazard simulation modeling of blended and 100% H2 pipelines and compared against equivalent relevant natural gas pipeline hazards. Operators will be better prepared to plan future updates to their pipeline safety measures & procedures with the results of the hazard models developed as part of this project.

Technical Concept & Approach



Toxic Threat Zone (Toxic Area of Vapor Cloud, Not Burning)



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

Results/Status

This report analyzes and compares gas release safety hazard modeling scenarios of 100% hydrogen pipelines and methane pipelines using two different free and publicly available safety hazard modeling software packages.

4 different hazard scenario types were tested on one software package and were modeled across a range of pipe diameter and pressure parameters (Thermal radiation zone from a jet-fire (hydrogen vs methane); Overpressure blast area from a vapor cloud explosion (hydrogen vs methane); Flammable threat zone (hydrogen vs methane); Toxic threat zone (hydrogen vs methane). These diameters and pressures were determined by the project sponsors.

Due to limitations in the tested version of the second software, it was used to model one type of hazard scenario: Thermal radiation zone from a jet-fire (hydrogen vs methane vs blends)

The modeling results from both software packages for hydrogen-vs-methane jet-fire scenarios agree with the hydrogen-vs-methane relationship predicted by the ASME standards (B31.8S for natural gas and B31.12 for hydrogen) Potential Impact Radius (PIR) formulas: hazard distances for thermal radiation from jet-fire leaks are predicted to be relatively lower for hydrogen leaks as compared to methane leaks.

The primary difference between the software packages and the ASME formulas with respect to jet-fire modeling is that the software modeling packages predict that the Level of Concern (LOC) threat distances for hydrogen are closer to methane than the ASME formulas predict. These differences could be due to differences in the assumed heat intensity values between the software packages and the ASME PIR formulas.

To model blended hydrogen pipeline scenarios, the software package was used to run jet-fire scenarios comparing various blend levels of hydrogen/methane against 100% hydrogen, and 100% methane. The software predicted that the estimated threat distances for jet-fire thermal radiation are gradually reduced compared to 100% methane as the percentage of hydrogen blend is increased.

The reverse trend is true for non-jet-fire hazard modeling (i.e. with either delayed or no ignition). These modeling scenarios predict estimated threat distances for hydrogen which are greater than for methane.

There is a proposed PHMSA research topic related to this subject. This potential future PHMSA-funded research could further explore the topics suggested by this report.

This project is complete. The final report of Safety Hazard Modeling of 100% Hydrogen Pipelines was completed and released to OTD members in June 2024.

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Material Inspection and Testing Training Program

The objective 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 the Gas Operators' systems.

Project Description

Utilities implement processes of qualifying materials and routinely inspecting and testing them before they are placed in service to control risks associated with the use of substandard products. This program creates training videos and interactive 3D models to train personnel to inspect and test products. Operators can use the training material in E-Learning, Mentoring, Hands-on, Instructor lead, or any other method of training they choose to implement it based on consideration of the type of work is being performed in the workplace.

Deliverables

Deliverables of this project include identifying and selecting a list of product types for training content, identifying, and subcontracting vendors, and partnering with manufacturers to deliver a Product Inspection Training Modules and a final report.

Benefits

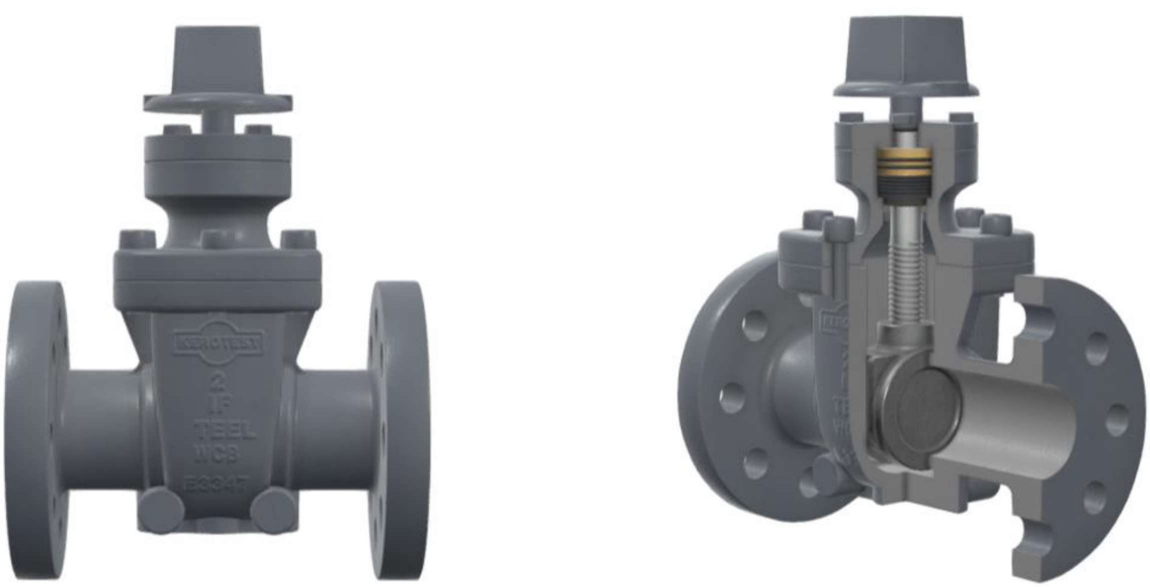
Participation in this program will improve consistency and quality of inspection and reduce the risks of making errors and reduce the risk of safety events or reportable incidents occurring. This program using advanced training technology can speed up the training, aid better comprehension, increase learning engagement, and improve training effectiveness. This will also aid in knowledge retention as a result of staffing changes.

Technical Concept & Approach

The main task in this project is:

Content Design, Test and Distribution

This task includes designing, planning, producing, testing, and publishing micro-videos and 3D interactive models for product types selected. This budget is based on creating up to 20 modules consisting of micro-videos, 3D interactive models, and quizzes.



Steel Valve 3D Model


HDPE Low Volume Tapping Tee 3D Model


Flange (left) and MSA Threaded Fitting (right) 3D Models

Results/Status

The project team identified product types for material inspection training content. The team created training content and shared it with manufacturers for feedback, which was incorporated into the training material. The 3D model vendor completed twenty models based on the requirements created by the team. The team also completed training scripts for seventeen product families for videographers.

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New Product Evaluation Program

The objective of this project is to create an ongoing program to qualify new products through testing to confirm that it meets the regulatory and industry standards requirements.

Project Description

This program creates an ongoing testing program of new products and materials selected collectively by the program sponsors. The new qualified products will provide operators with an alternative to the materials/components that are currently approved and used by operators.

Deliverables

The deliverables for this project include an ongoing testing program of new products and materials for which an approved product list will be created and maintained, and a final report summarizing the test results.

Benefits

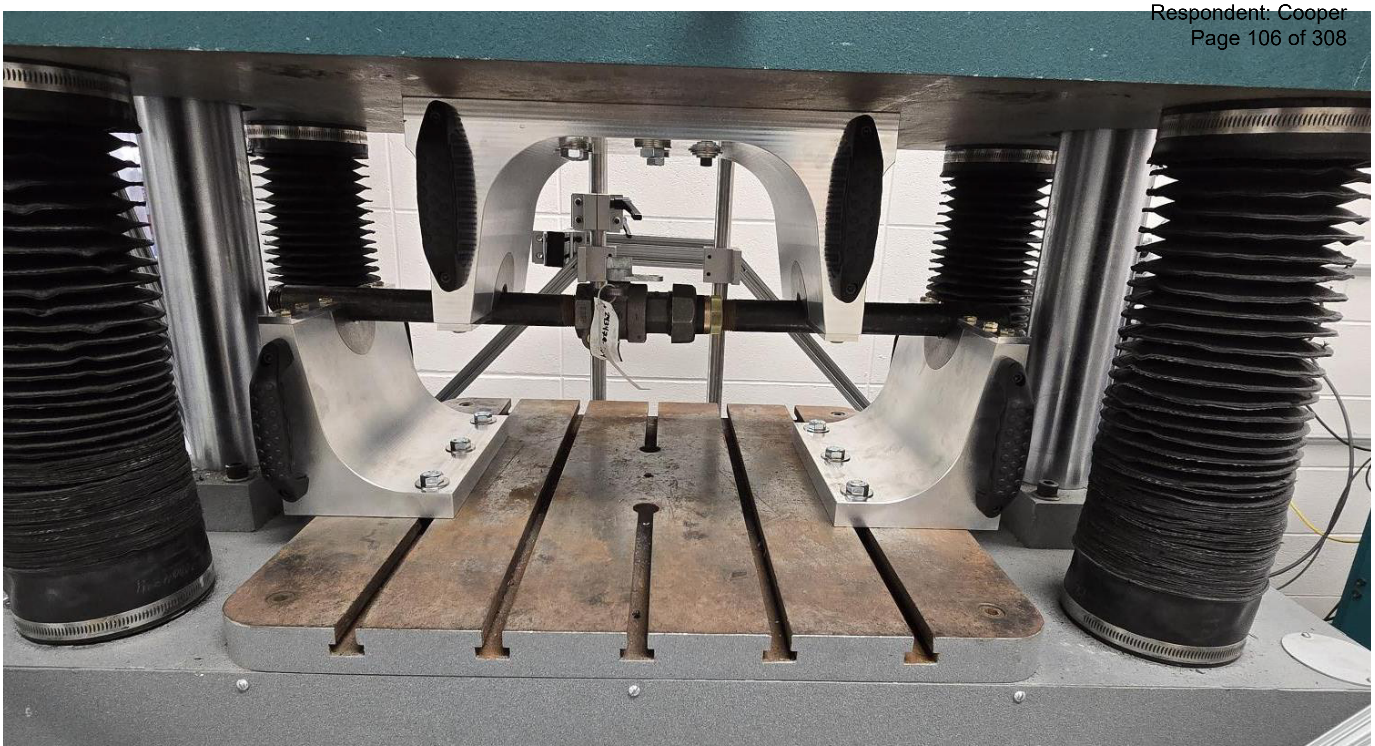
Operators' supply chains often look for alternative materials/suppliers to create contingencies, mitigate the issues of bottlenecks to stay resilient and adapt to significant disruptions. Many utilities test new materials before installing them in their systems to ensure quality, regulatory compliance, and safe operation. Sometimes operators test new products by themselves, which can be costly and time consuming, and others have limited resources to perform these tests. This new program will complement another ongoing program of product and process validation under which existing products are tested to the requirements of industry standards to confirm compliance and ensure that process and product changes implemented over their lifetime have no detrimental effect on their fit, form, and function.

Technical Concept & Approach

For this project, the team will procure, prepare, and test samples. Testing for new products will be based on regulatory requirements.

Meter Valve Twist Test fixture

Temperature Resistance Test setup



Bend Test fixture

Results/Status

The project team has completed several key tests on MDPE and HDPE pipes and valves. The dimensional analysis confirmed that both MDPE and HDPE samples comply with ASTM D2513 specifications. Squeeze-off testing is ongoing, with pipes being tested for 1,000 hours under specified conditions. Sustained pressure testing at 73°F is also underway, with HDPE and MDPE pipes undergoing tests at different hoop stresses. HDB validation tests revealed that all MDPE specimens exceeded the 200-hour requirement, while testing of the HDPE specimens is still in progress. Minimum hydrostatic burst pressure tests indicated that all specimens surpassed the required standards, failing in a ductile manner. Polyethylene ball valves have successfully passed shell, seat, operational, and sustained pressure tests as per ASME B16.40-2008 and ASTM D2513-2024.

The team has set up and initiated various tests for ball meter valves in accordance with ASME B16.33-2012(2017), including gas tightness, bending, temperature resistance, and strength assessments.

Gas Tightness Test setup

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Commercialization of Over-Pressurization Protection Device

The objective of this project is to work with a manufacturer/distributor to further develop and commercialize the existing Over-Pressurization Protection Device.

Project Description

The project team will start with the working over-pressurization protection prototype and collaborate with a manufacturer/distributor to refine the design using their knowledge and expertise to reduce the size of the device and make it easier to produce, manufacture, and assemble.

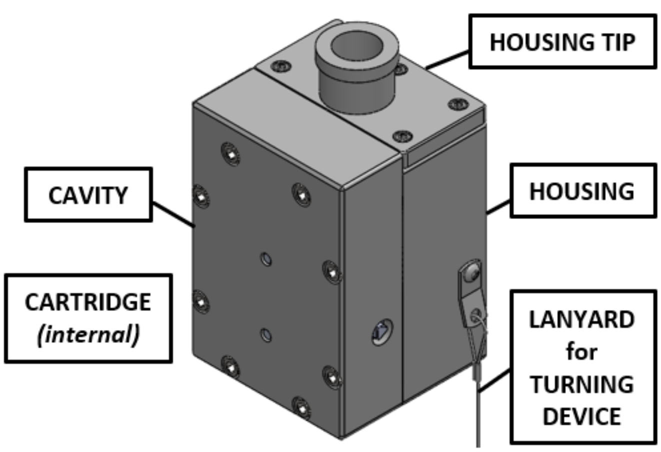
Deliverables

Deliverables for this project included: a refinment of the design of the Over-Pressurization Protection Device, a prototype of this updated design from the manufacturer/distributor and perform testing of that prototype at GTI Energy and manufacturer. Depending on the remaining funds for the project after the testing has been completed, the project team plans to send some prototypes to the project sponsors for review.

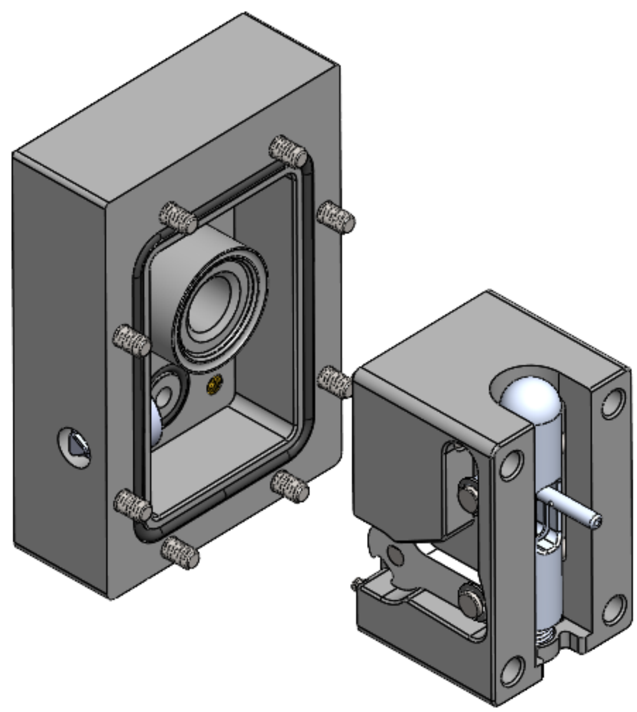
Benefits

Following the Merrimack Valley incident there has been an increased emphasis on protecting homes from accidental over-pressurization events. While there are slam-shut regulators with automatic shut-off valves which protect homes from these over-pressurization events, there are currently no over-pressurization protection devices on low pressure gas lines since they do not need downstream regulators.

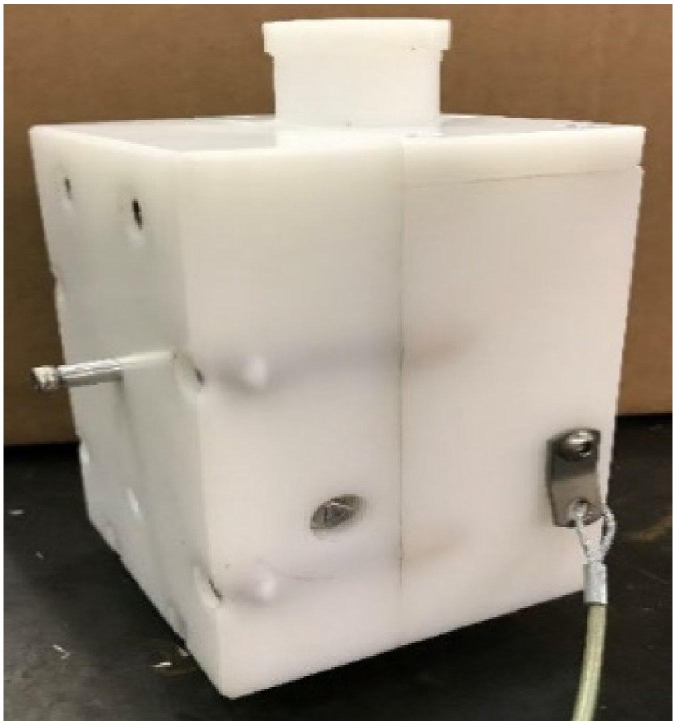
This device will protect homes supplied by low-pressure distribution lines from an over-pressurization event which is caused by accidentally bypassing a critical upstream regulator. This automatic shut-off valve will prevent any higher-pressure gas from reaching the meter and the house, protecting the customer.



OPPD Beta Prototype (Resettable)



Beta Prototype (Resettable) – Alignment of Cartridge into Cavity



Assembled Resettable Beta Prototype

Technical Concept & Approach

Specific tasks in this project include:

Design Refinement

The project team will work with a manufacturer to refine the design of the Over-Pressurization Protection Device using their domain expertise as well as input from the project sponsors. This process will involve multiple design reviews between the project team and manufacturer until a design has been finalized and a final Beta Design of the Over-Pressurization Protection Device has been produced.

Production of Prototype

The project team will work with a manufacturer to produce a working prototype of the Over-Pressurization Device.

Lab Testing of Prototype

The project team will perform testing of the working prototype of the Over-Pressurization Protection Device to validate its performance. This testing may include, but is not limited to: evaluation of performance at the designated pressure trip-point, burst test to determine maximum pressure before leaking, and flow test to verify adequate supply of air through the device at low pressures.

Results

The design of the Gamma Prototype evolved over the course of the project with the following significant changes made to reduce the number of components (especially those extending outside of the housing) and to reduce the overall size of the device. The integrated seal on the sealing plunger was improved based on a previous design. A diaphragm was introduced to seal the internal cavity from the atmospheric pressure behind the trip piston, while allowing for better movement of the trip piston without the use of an o-ring. The reset mechanism became an internal control pin directly attached to the sealing plunger, which could be accessed via a removable face with an integrated pop-off pin once the pop-off pin indicated that there was no pressure in the device.

A third-party manufacturer fabricated the metallic and plastic components of the Gamma v3 Prototype, while GTI Energy obtained the remaining hardware and 3D-printed components. The team assembled the Gamma v3 Prototype and performed preliminary testing to evaluate the overall trip mechanism and to optimize the force of the linear spring which pushes the sealing plunger towards the seal as well as the material and geometry of the 3D-printed rubber-like diaphragm to allow for proper movement of the trip mechanism. Based on the results from this preliminary testing, the team began developing the Gamma v4 Prototype to incorporate improvements identified during this testing process. The team also identified a method to determine the friction and the effective surface area of the locking piston to better predict the trip pressure for the final prototype.

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OTD Operations Technology Development

Developing Acceptance Criteria for Mechanical Tapping Tee Anomalies

The goal of this project was to evaluate the condition of exhumed PermaLock® mechanical tapping tees installed in gas distribution systems and develop guidelines for their inspection.

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 risk to the operator's system such fittings may pose. This project was designed to help natural gas operators:

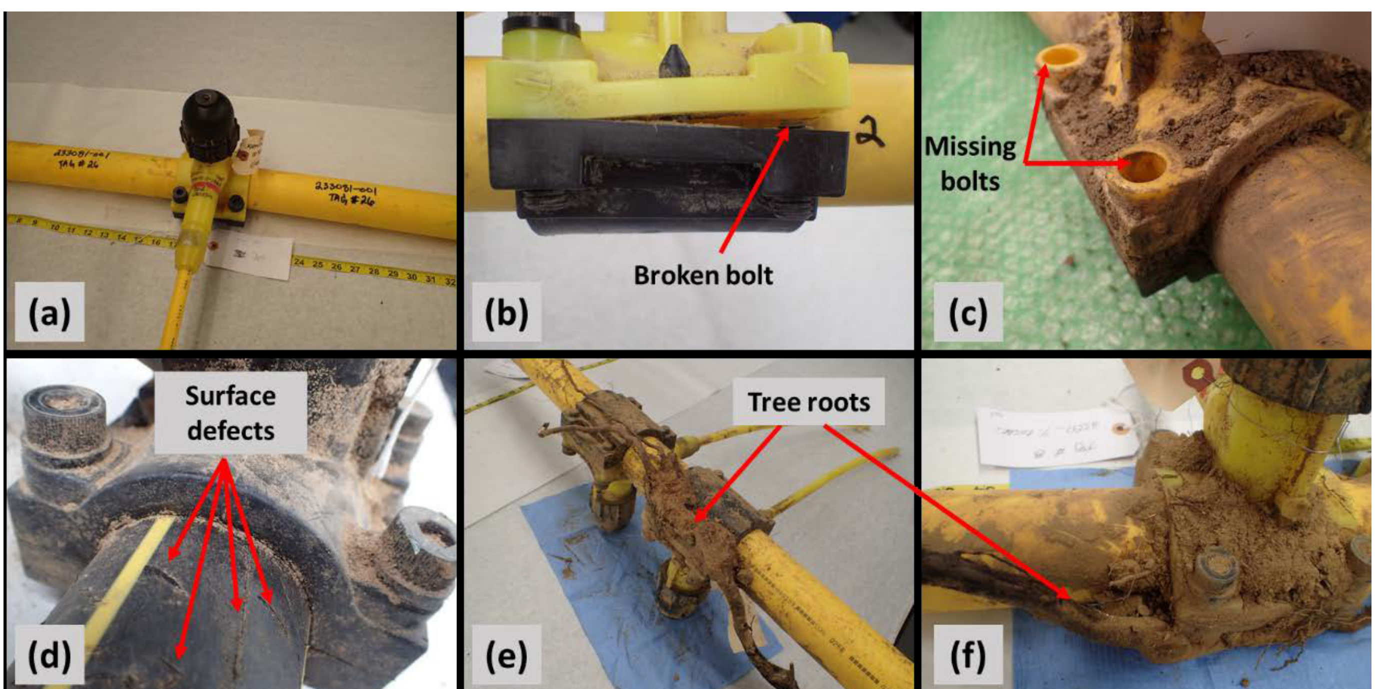
1. Evaluate the condition of the exhumed PermaLock tee fittings.
2. Develop field acceptance criteria.
3. Determine if the fittings need remediation.
4. Propose a plan to address improperly installed fittings.

Phase 1 examined and evaluated a subset of PermaLock tee fittings attached to main pipes.

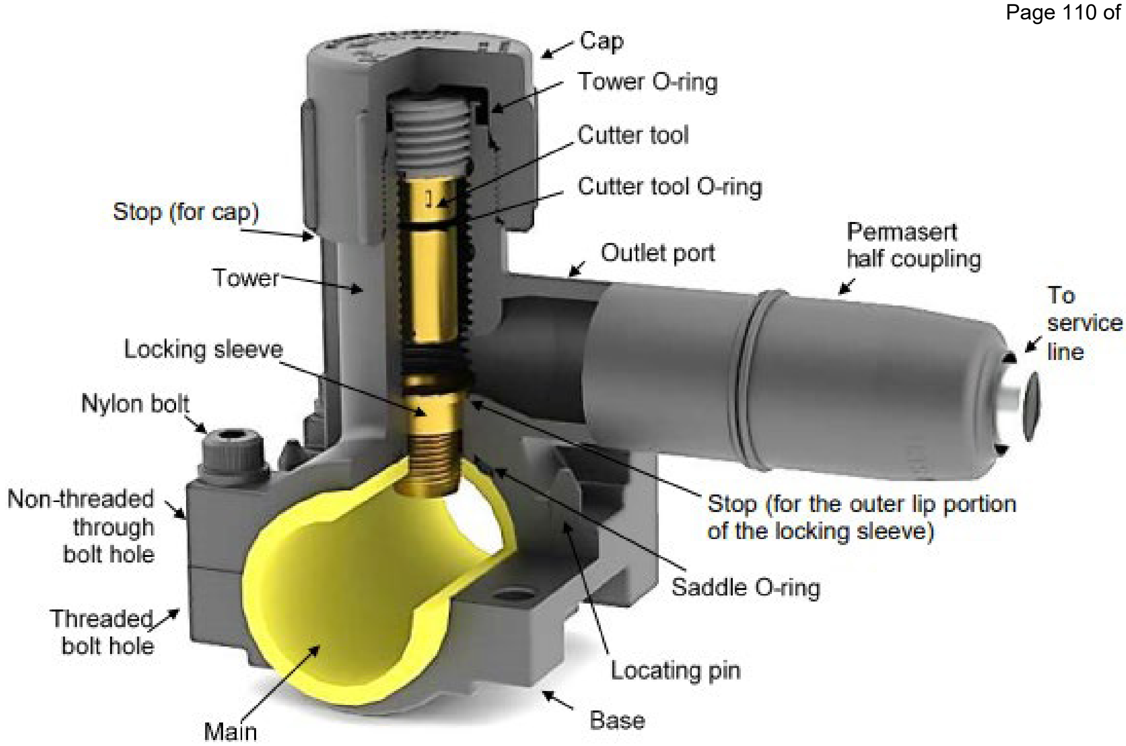
Phase 2 is intended to integrate the data from Phase 1 into an advanced fault tree analysis model that would aid operators in better understanding the impact of these fittings to their respective system risks.

Deliverables

The objective of the overall project was 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. This criterion provides guidance for operators to evaluate component anomalies and, if needed, determine appropriate remediation.



Examples of observations made during external inspections of the sample set.



Cross-section diagram of a Permalock Mechanical Tapping Tee.

Benefits

The project assists operators in identifying, reviewing, and mitigating potential risks associated with different fittings, and developing a field acceptance criterion.

Technical Concept & Approach

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

Results/Status

Sixty-one (61) samples were provided to the team and evaluated using external examination, internal visual examination, and CT X-Ray. These samples were cataloged, and each was assigned a distinct sample and batch number within the LIMS database to ensure traceability.

The team 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, a variety of observations were noted on the sample fittings, such as installation anomalies, broken bolts, and insufficient locking sleeve engagement. Further extensive data collection and analysis will be crucial to confirm these initial observations, to understand their broader implications, and to quantify how different these observed anomalies are from the documented operational experience of other gas distribution companies. Currently, it is not definitive if these anomalies pose a risk to the reliability of the PMTT.

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

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OTD Operations Technology Development

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

The objective 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

The goal of this project is to determine if P/AC tubing can be effectively joined to MDPE tubing using electrofusion 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.

Deliverables

Deliverables of this project include a list of new material to test, sampling plan, and test methods and a final report.

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 over time. This research will allow operators to safely operate vintage and dissimilar piping systems which are connected to modernized pipelines and ensure connection and joining practices are sound.

P/AC pipes being joined by a MDPE electrofusion coupling

Technical Concept & Approach

The primary task in this project is:

Evaluations of Joining Methods

Electrofusion (EF) Joining:

The project team will develop a test matrix that includes variations in test conditions and measurements to assess joint integrity, and prepare standard fused assemblies at 73°F, -10°F, and 120°F ± 3.6°F using the fitting manufacturer's joining procedure.

The team will evaluate the fused assemblies by performing elevated temperature sustained pressure tests per ASTM D2513 and Fusion Evaluation Tests (FET) per ASTM F1055. If the fusion integrities are deemed unacceptable, the team will prepare additional fused assemblies by modifying the fusion process to impart less energy during the fusion process. This may be achieved by reducing the fusion time manually and evaluating these fused assemblies by performing the tests.

If joining P/AC to P/AC is successful using EF couplings, the project team will then evaluate using EF couplings to join P/AC to MDPE tubing. The team will repeat the above process.

The project team will review the initial evaluation of EF coupling joining with Nicor Gas and may seek input on the level of interest and viability for a manufacturer to either recognize variations in application of their EF product or develop a new product to meet the identified need. Based on this review, the team will determine the next steps, including whether to proceed with a full battery of ASTM F1055 testing.

Results/Status

The hydrostatic pressure testing based on the Rate Process Method (RPM) was replaced by the Elevated Temperature Sustained Pressure Test Method of

Specimen 242249-011, Ductile failure in pipe

Specimen 242249-013, Ductile failure in pipe

ASTM D2513-18a. The reason for this change was that the team had chosen relevant stresses based on the Lifetime Prediction Model (LPM) for MDPE pipes, but the team encountered samples that lasted both much longer and much shorter than anticipated.

The project team monitored the testing of several fused assemblies prepared at room temperature, -10°F, and 120°F. These assemblies were tested under sustained pressure at 176°F. Fused assemblies were also prepared for the Fusion Evaluation Test (FET).

A total of 24 fused assemblies, prepared across the three temperature conditions and tested at 176°F under 670 psi hoop stress, successfully exceeded 170 hours of test duration. These results meet the sustained pressure test requirements specified in ASTM D2513. Ductile failures occurred exclusively in the pipe segments, well away from the fusion joints.

No brittle separations were observed in any of the FET-tested specimens. However, voids covering approximately 20% of the fusion zone were identified in one specimen. One void accounted for 12% of the fusion zone length, and another covered 8%. These voids are attributed to the electrofusion process, during which molten material flows into air gaps between the fitting and pipe, followed by shrinkage as the material cools.

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OTD Operations Technology Development

Guidance for H2/NG Blending Equipment Installation and Operations

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

Project Description

The project will document the required equipment to successfully inject blended hydrogen/natural gas into a gas distribution system. The team will obtain industry subject matter knowledge from stakeholders and/or manufacturers of electrolyzers, hydrogen storage, and blending skids; document the procedures for the installation of required blending facility equipment; and document the continued blending operations and maintenance requirements within the blending facility.

The project will evaluate potential hydrogen end uses for any excess hydrogen production (e.g., hydrogen fuel cells to support microgrids or to provide on-site power, hydrogen supply for refueling stations). Perform a financial estimate of the associated equipment and operational costs (e.g., utilities, maintenance).

Deliverables

Deliverables of this project include a summary of hydrogen equipment required for blending, the capabilities of commercially available equipment, meeting minutes with manufacturers and operators, a recommended practices and operating procedures document for required equipment, an estimate of capital and operating costs to implement hydrogen blending projects along with the process of how to create an estimate, and a final report.

Benefits

This project will provide procedures and recommended practices to guide operators in planning and executing hydrogen blending projects. The financial analysis will also assist operators in understanding the investments required for implementation.

Technical Concept & Approach

Specific tasks in this project include:

Technology and Usage Review

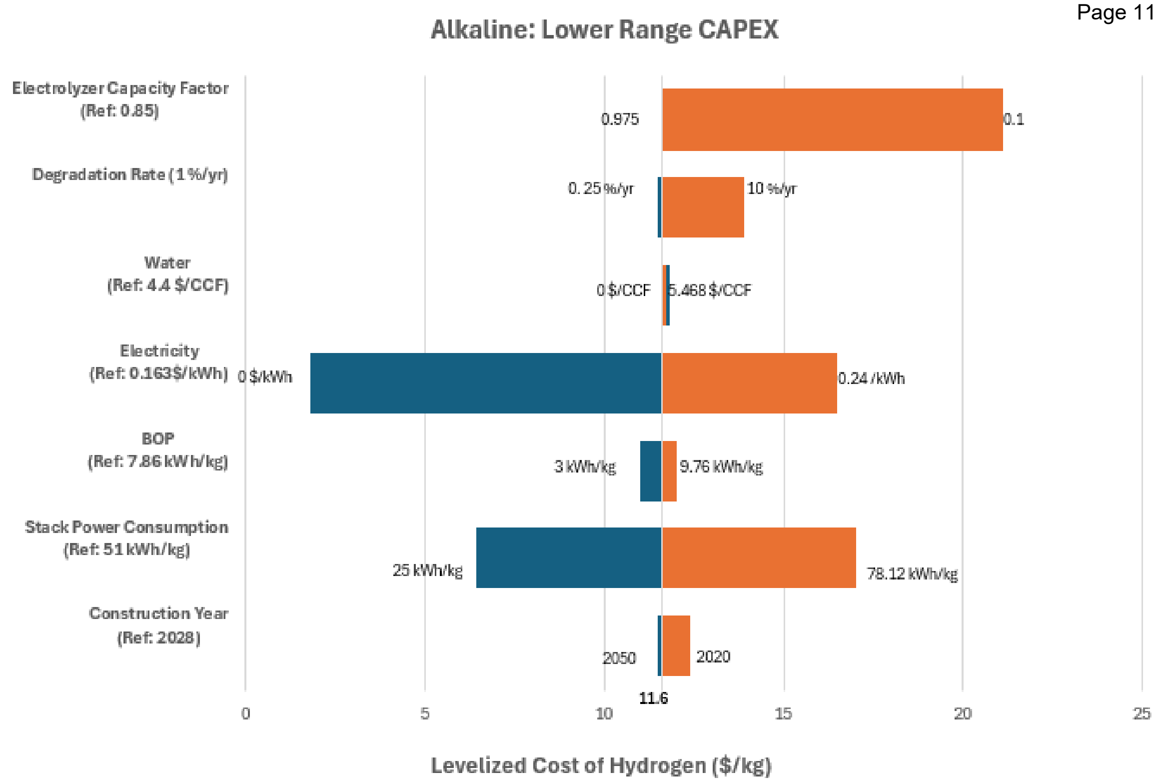
The work in this task includes identifying the equipment used in previous hydrogen blending pilot projects, operating conditions, and other current commercially available equipment that can be used for hydrogen blending and hydrogen projects. This task will involve reviewing equipment specifications and interviewing manufacturers and operators on equipment capabilities and any lessons learned.

Recommended Practices and Operating Procedures Development

The work in this task includes developing recommended practices and operating procedures based on codes and standards and insights gained from the manufacturer and operator interviews. This task will also include a review of past incidents and their root causes to develop mitigative measures. The procedures and recommended practices will cover installation, start-up, and maintenance of hydrogen blending systems and auxiliary equipment.

Financial Analysis

The work in this task includes conducting an analysis of the anticipated capital and operating costs associated with hydrogen blending projects. Depending on the availability of data from manufacturers and operators, different sets of calculations may be performed, i.e., one analysis per major U.S. region (West Coast, Midwest, East Coast, etc.).



Tornado Diagram for Alkaline Electrolysis System (2028 Construction Year)

Results/Status

This study covered a H2 blending facility that is used to inject H2 into a distribution network, with the following equipment: an electrolyzer (Proton Exchange Membrane (PEM), Alkaline, or Solid Oxide Electrolyzer Cell (SOEC)),above-ground non-bulk gaseous H2 storage (containing < 5000 scf),A blending skid, auxiliary equipment and components (e.g., chiller, deionizer, pressure regulators, valves),safety equipment (e.g., gas detectors), and a control system (e.g., flow, composition, temperature).

The operators interviewed shared various lessons learned and recommendations pertaining to system design and maintenance, such as recommendations for oxygen pipingmaintenance of the water system, freeze prevention and temperature monitoring, and the life expectancy of

The financial analysis research covered a high-level financial analysis of a H2 blending facility with on-site electrolytic H2 production and storage. Several factors can significantly affect the Levelized Cost of H2 (LCOH), such as stack power consumption, the cost of electricity, and electrolyzer capacity factor. The LCOH can be reduced by sourcing lower-cost electricity (e.g., co-locating the site by solar and wind sources), procuring electrolyzers that are more efficient, and/or enabling relatively continuous system operations. The LCOH estimates from this project are higher than those from other studies due to different assumptions used (e.g., production capacity, electricity cost). These key factors can significantly impact LCOH. To conduct an accurate project-specific cost analysis, information such as facility size, electricity cost, operations frequency, are needed.

The purpose of the financial analysis here is to provide a high-level estimate of the capital and operating associated with a H2 blending distribution facility, as well as to identify the key factors that impact these costs. Furthermore, it is important to note that project costs can vary significantly based on geographical location, on equipment, on materials, and on contractor services.

This project is complete. The final report on Hydrogen Blending Recommended Practices and Operating Procedures was completed and released to OTD members in February 2025.

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High Pressure Hydrogen Testing of Sealants and Gaskets

The objective of this project is to determine the effect of higher-pressure hydrogen-blended natural gas (20% & 100% H2) on thread sealants and gaskets at multiple temperatures.

Project Description

As part of OTD 5.18.w, GTI Energy evaluated 17 different types of thread sealants to see how they performed on Schedule 40 Black Steel and 304 Stainless Steel pipe assemblies. This project will further test the 9 most promising thread sealants using 100% H2 and a natural gas/hydrogen mix with 20% H2.

Deliverables

Deliverables for this project include: a thread Analysis Results Report, a test Matrix, and a final report which will document the results from the lab testing.

Benefits

The results of this project will give operators greater confidence to safely deploy high pressure (>60psig) hydrogen blends while minimizing leaks to atmosphere. This project will provide operators with more information to help consider displacing larger volumes of conventional natural gas with hydrogen-blended natural gas within their higher-pressure systems.

Technical Concept & Approach

Specific tasks in this project include:

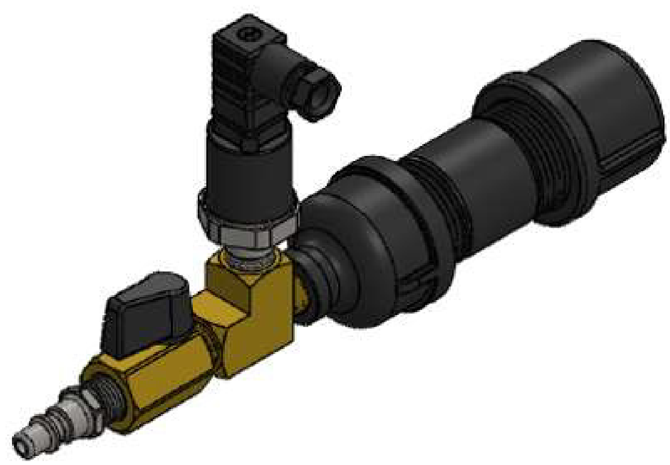
Test Preparation

Create a test matrix and acquire the various thread sealants and gaskets which will be tested. Additionally, the team will acquire the high-pressure hydrogen-blended natural gas for testing. This task will also involve sending out the thread nipples for analysis to ensure that they pass the requirements per ASME B.1.20.1.

Lab Testing

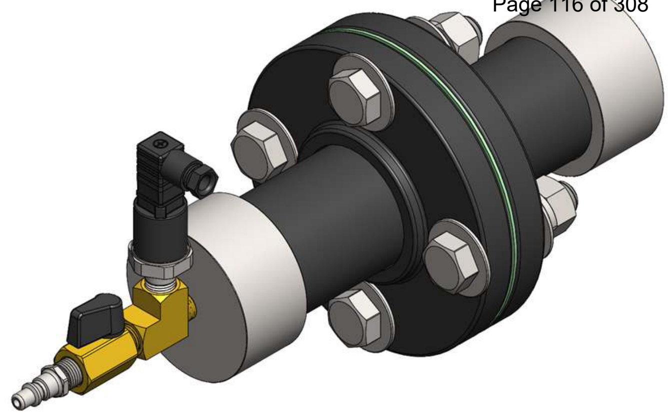
Perform lab testing of the various thread sealants and gaskets at multiple pressures and temperatures. The initial testing will be a pass/fail test of the thread sealants and gaskets in a water bath to determine if there is any leak. The subsequent testing will be performed on the thread sealants and gaskets that pass by analyzing the internal pressure decay using a pressure transducer. That pressure decay will then be converted to a volumetric leak rate.

Black Steel 1 NPT Threaded Test Sample (1 NPT to ¼ NPT Reducer – 3in Long 1 NPT Pipe Nipple – 1 NPT Cap)



Pressure Transducer Subassembly attached to Black Steel 1 NPT Threaded Test Sample

Proposed Black Steel 2 IPS Gasket Test Sample (Tapped 2 IPS Cap – 4in Long 2 IPS Pipe Nipple – Socket Weld 150 Class 2 IPS Pipe Flange – Test Gasket)



Pressure Transducer Subassembly attached to Black Steel 2 IPS Gasket Test Sample

Results/Status

Test Procedure for the Temperature Cycle Leak Test for this project will be nearly identical to the Test Procedure for the Temperature Cycle Leak Test for OTD 7.21.j, except the starting pressure will be higher for the Threaded Samples and will need slight modifications for the Gasket Samples. The Job Safety Analysis (JSA) for the Elevated Pressure Leak Test in the water bath has been completed and a test matrix has been created for the gasket testing. The project team received the 24 welded pipe assemblies necessary to perform gasket testing.

The team is actively working to upgrade temperature chambers with a safety purge system. All test materials have been ordered and/or received, and high-pressure temperature cycle testing will begin as soon as a temperature chamber is ready and available.

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Operations Technology Development

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

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

Project Description

The initial phase of the project would perform a literature search and study of long-term heat induced aging of PE. This would be combined with deployment of sensors in the field to collect soil temperature, moisture, and other parameters to inform the study.

Deliverables

Deliverables of this project include 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, and a final report.

Benefits

Accurate remaining lifetime data will help operators use risk-based data to drive funding and the scheduling of remediation for assets (PE pipe). Additionally, vintage PE pipe, which has been identified as a source of emissions, can be remediated before leaks occur.

Technical Concept & Approach

Specific tasks in this project include:

Literature Review

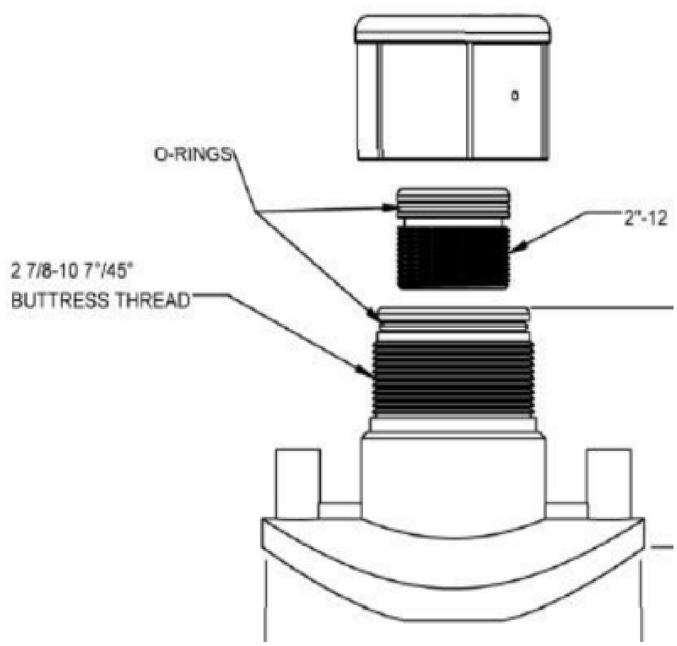
This task will compare the past work done by the project team with more recent developments by others. The team will perform a literature review to capture information relevant to aging infrastructure and elevated soil temperatures, establish the data requirements to improve PE lifetime estimation, and review the available data and determine what gaps there are that need to be addressed.

Model Testing

This task will develop and test the model identified in literature review. Testing will use sponsor provided data, sponsor provided PE samples, data predicted by normal climatic conditions, and data captured by field measurements. If indicated by the initial model test results, additional field data capture and sample testing will be conducted. This could include collecting PE material from in-service pipes or direct measurements on the gas stream.

Field Data Acquisition

This task will verify that field data relating to PE samples is available. This includes soil temperatures and other conditions where the samples were



obtained. If the data is not already available from the sponsors, the team will develop a field deployable system to measure the soil temperature, soil moisture, and other parameters not requiring direct contact with the pipe. The team will test these systems on the GTI Campus.

As indicated by the model testing, additional field data may be required to reach the desired level of accuracy. This could include samples of PE from in-service pipes and measurements of gas temperature and flow. If required, a measurement system will be developed that can, through a fusion fitting, retrieve a coupon of the PE material and insert sensors into the gas. This technology or tool will be developed and tested at the project team facilities.

Sample Analysis

This task will process existing PE samples provided by the sponsors and any additional samples acquired during the field measurement. The team will summarize the sample test data in conjunction with metadata for the time and location of sample collection and correlate the measured sample conditions with those predicted by the field measurement model.

Results

The project team developed and discussed a test matrix with sponsors.

The test matrix was formulated to provide guidance as to the number of PE samples required to establish the Oxidative Induction Time (OIT) of the material. The OIT would quantify the resistance to oxidation of the samples, an indicator of remaining service life. The OIT test specimens will be extracted from PE pipe samples but will exclude both the interior and exterior surfaces of the pipe; this is to ensure non-oxidized material is used for the study. The team determined that a minimum of 80 samples per material are required to rigorously establish the remaining life.

Status

The project team has identified one sponsor with a supply of well-documented samples they can provide. The project team is engaging all sponsors to determine if others are available. After receiving the PE samples, they must be physically prepared for accelerated aging. Aging requires at least 1000 hours with up to 4000 hours for optimal results. This is followed by OIT determination and test data analysis.

The project team expects to start receiving PE samples during Q2 of 2025

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Operations Technology Development

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

The objective of this project is to identify the factors contributing to the Unaccounted-For (UAF) gas volume in the natural gas distribution system.

Project Description

The estimation of Unaccounted-For (UAF) gas is system-specific, and it varies widely between utilities. Since UAF is caused and impacted by many factors, the proposed data analysis will look at the variabilities of most of the affecting factors in utilities' records. These factors include pressure, temperature, meter readings, accounting procedures, and theft records.

The project team plans to work on case studies with utilities which have records of the measurement components of vented emissions, meter reading records, and their system characteristics to include in the analysis of the contributions of accounted emissions and other unaccounted for estimates.

Deliverables

Deliverables of this project include a description of the study process, data collected, and general findings, a quantification of the effects of different sources of UAF gas and identification of areas of concern or improvement, and a project summary with a comprehensive overview of the results for public distribution.

Benefits

The project identifies the contributions to UAF gas from the four main areas of accounting, measurements, operation, and theft. 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

Specific tasks in this project include:

Data Collection and Review

This task includes identifying data sources, collecting, and reviewing the data provided by the participating utilities. The data collection procedure includes review of operation and maintenance manuals and specifications to evaluate the contributions of operations procedures to gas loss.

Assessment of UAF Sources

This task includes an analysis of the available data and review of gas meters and regulators measurement practices. The analysis also includes a review of gas leakage estimates from operational practices, such as repair and line purging, that may affect UAF estimates.

Investigate Specific Factors Associated with UAF

This task includes a review of results provided by the utilities of laboratory-controlled experiments on gas meter sets. The review will evaluate the effect of the flow control, meter tube roughness, and temperature on the bias and accuracy of the recorded gas consumption at low flow rates.

Results/Status

Data collection and review are in progress. The review of the results revealed that there is no significant correlation between meter age and accuracy.

Overall, the meter population tended to prove slightly fast compared to the proof meter, and meter accuracy based on these findings would tend to cause UAF gas to be more negative (more gas sold than purchased).

The accuracy results for residential and small commercial size diaphragm meters (2 Foot drive)

were most prevalent in the data. Approximately 122,000 meters fell into this category.

The results for each year varied slightly, with the combined results for all years indicating that about 4.3% of the tested meters proved greater than 2% fast, and about 2.9% proved greater than 2% slow.

As context, the California Public Utilities Commission (CPUC) requires that meters coming out of Service to test between 2% slow and 1% fast. Commonly used industry manufacturing standards (ANSI B109) require that all new meters meet these standards within +/- 1% accuracy when received from the manufacturer.

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OTD Operations Technology Development

Evaluation of Viega MegaPress Fittings

The objective of this project is to investigate Viega MegaPress fittings and validate their performance as an effective 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

Deliverables of this project include an evaluation of fitting types to be tested and a final report.

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

Specific tasks in this project include:

Design and Build Testing Rig

The work in this task includes designing, fabricating, and building the test rigs to be used for testing the Viega MegaPress fittings at the project team lab facilities. This also includes the testing rigs for comparative testing (i.e. threaded fittings, flanged fittings, etc.)

Investigate Applicable Standards

The work in this task involves researching the applicable standards for mechanical fittings used on CFR 192 jurisdictional piping (steel piping only) and working with the fitting manufacturer to define any further required component testing.

Perform Lab Testing in Conformance with Applicable Standards

The work in this task includes using the custom testing rigs to perform lab evaluations of Viega MegaPress fittings and comparative fittings. This includes proposed tests such as: leak testing, tensile pull-out resistance, corrosion resistance, and thermal cycling tests.

Results/Status

The project team finalized the designs for the test rigs and a comprehensive testing matrix was prepared. The test plan was drafted, reviewed, and approved in collaboration with Viega, aligning with the project's objectives and standards. The team conducted a site visit to Viega's training headquarters in Broomfield, Colorado, where they observed facilities and received training on proper fitting installation techniques.

The project team is actively acquiring the remaining materials and preparing for rig assembly to ensure testing can commence promptly upon delivery of the Viega fittings.

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Operations Technology Development

NDE for Plastic Pipeline Inspection

The objective of this project is to demonstrate the probability of detection of different categories of anomalies in plastic pipe assemblies when using phased array ultrasonic tool (PAUT).

Project Description

This OTD project is designed to be a stand-alone collection of tasks that provide cost share for a larger CEC project "Plastic Pipeline Deficiency Inspection for Pipeline Integrity Management". The OTD project picks up the scope of work for CEC Project Task 4: NDE Evaluation of Pipe and Joints. The goals are to extract pipe and joint assemblies from the field, perform Phased Array Ultrasonic Testing (PAUT) Non-destructive evaluation (NDE) inspections on the assemblies, verify the NDE indications via x-ray computerized tomography (CT) scanning, categorize the defects discovered, develop the confusion matrix for the various categories of defects found in the assemblies, perform accelerated lifetime analysis on the assemblies, and to correlate NDE indications to expected residual lifetime of the assembly given the defect indications for each category of defect. The primary objective of this effort is to demonstrate the probability of detection of different categories of anomalies in plastic pipe assemblies when using PAUT tools.

The secondary objective is to develop a correlation of indications found to the expected residual lifetime of the asset given the indication of defect. The tertiary objective is to integrate the information provided by the Non-destructive evaluation (NDE) inspections into the risk assessment models. These risk assessment models will fuse multiple sources of information pertaining to the integrity of the pipeline system being evaluated. This approach will allow the development of comparative metrics to compare risk profiles developed without NDE information to those developed with NDE information. The risk assessment information will be incorporated into a holistic integrity management decision support framework culminating in risk-spend-efficiency (RSE) and other stakeholder defined metrics. These metrics will allow comparison of impact to integrity management and stakeholder objectives with, and without NDE information.

Deliverables

Deliverables for this project include a detailed sampling plan of the project, a defect category confusion matrix report, an accelerated lifetime testing report, a correlation of indications of expected lifetime report, and a final report.

Benefits

This technology can enhance the consistency and repeatability of inspections of plastic pipes and joints. An effective non-destructive evaluation (NDE) method for plastic pipe and joints will assist operators in understanding the proportion of critical defects in their plastic piping systems that need to be addressed.

Technical Concept & Approach

Specific tasks in this project include:

Scheduling Sample Acquisition

A gas distribution utility is supporting the CEC proposal and will work with the project team to select regions with characteristics of interest for extracting pipe assemblies damaged by third party hits. The project team has shown in an earlier PHMSA project that third-party hits are a valid quasi-random sampling approach for exploring the proportions of pipes and joints with varying levels of internal defects. In this task the team will discuss collaborating with National Geospatial-Intelligence Agency (NGA) in the northeast using the same methodology to address historic fusion inspections.

Develop Defect Category Confusion Matrix Report

In this task the team will inspect assemblies removed from the field for evidence of internal cracks and fusion anomalies. Each assembly will be inspected with x-ray CT for an absolute measure of defects present. The same assemblies will then be inspected with PAUT. Comparing the two inspection results will allow us to develop the confusion matrix that defines the probability of detection, false positives, false negatives and other quality metrics for each defect category. This analysis will enable us to provide definitive input for which categories of defects PAUT is a useful tool.

Develop Accelerated Lifetime Testing Report

In this task all assemblies inspected will be destructively tested through long-term hydrostatic testing for internal cracks, and quantitative joint quality tests for joints. This work will allow us to relate indications of defects to lifetime expectancy of the assemblies.

Develop Correlation of Indications to Expected Lifetime Report

This task will be focused on data analysis and data modeling to convert NDE indications into decision support information.

Results

The project team communicated with RICE to plan training on Phased Array Ultrasonic Testing (PAUT) technology and scope of consultations. The entire team was involved in preparing for the PAUT training week. These preparations included specification of equipment, ordering equipment, preparing reference specimens, x-ray CT scanning of reference specimens, and coordination between the RICE and project teams.

A significant project work was performed by the RICE team who delivered the PAUT training manual for proper use of the PAUT technology on polyethylene piping systems. The manual is 109 pages of theory, techniques, and specific polyethylene piping component scanning methods.

Status

The next task for the team is to design a database for the project test results.

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OTD
Operations
Technology
Development

Evaluation of PLCS Bonded Saddle Tee

The objective of this project is to evaluate if PLCS's epoxy bonded saddle tee has adequate torque resistance for tapping threaded holes in a cast iron main.

Project Description

The PLCS Bonded Saddle technology is a system on the market sold in the UK by parent company ALH for drilling tap holes in steel and cast-iron gas mains from 12" to 48" in diameter at operating pres-sures up to 30 psig. The bonded saddle technology uses a special epoxy bond mixture to secure the saddle to the top of steel or cast-iron mains. This saves operators time and money vs. traditional tapping saddles because only the top of the gas main needs to be exposed. This results in less excavating, shoring, and backfill, less chance of facility damages, and reduced risk of unsupported main. Operators in the US typically drill and tap threaded holes into pipelines and therefore require a system that is proven capable of withstanding the torque necessary to tap threads into cast iron.

This project will test and evaluate the PLCS bonded saddle for its ability to withstand the torque necessary to drill and tap up to a 5" NPT threaded holes in cast iron main.

Deliverables

Deliverables for this project include: a demonstration of PLCS's epoxy bonded saddle tee to show it has adequate torque resistance for tapping threaded holes in a cast iron main; analysis of the generated test data; and a final report.

Benefits

Utilities are seeking more cost-effective ways to do their work and reduce O&M costs. Reducing the time and labor needed to tap cast iron main is one area of need. This technology saves operators time and money vs. traditional tapping saddles because only the top of the gas main needs to be exposed. This results in less excavating, shoring, and backfill, less chance of facility damage, and reduced risk of unsupported main.

Technical Concept & Approach

Specific tasks in this project include:

Bonded Saddle Training and Application

The work in this task requires a PLCS operator to be present on-site and to train team members to prepare samples for testing per "ALH Bond & Bolt Instructions". This also includes time for safety orientation of PLCS personnel with on-site policies and procedures.

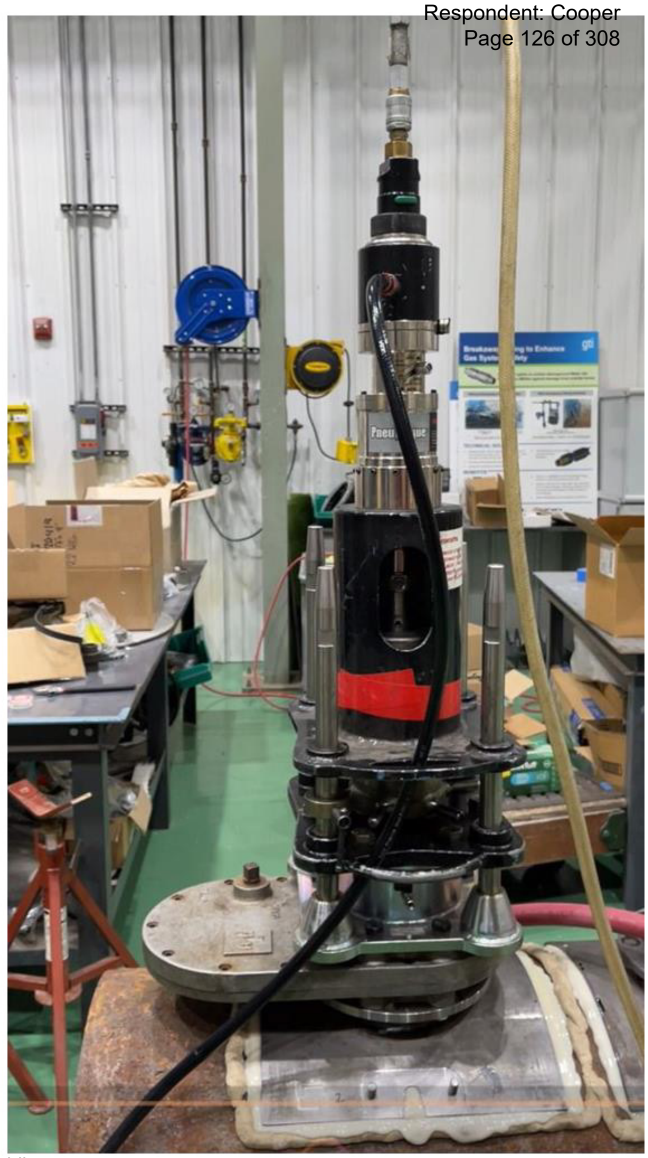
Data Analysis and Reporting

The work in this task includes documenting all the steps for application of the bonded saddle, documenting the findings, and the test results.

Results

The team evaluated the epoxy bonded saddle tee system available from PLCS/ALH to determine if the bonding system has sufficient strength to resist the torque necessary for drilling and tapping a threaded hole in cast iron mains and to pass a subsequent 24-hour pressure test at 20 psig.

The tested 16" and 24" bonded saddle systems from PLCS/ALH performed successfully and remained gas-tight after drilling and tapping operations were conducted. The tests were performed on a 4-ft long sample of 16" diameter cast iron main acquired from a utility company and two 5-ft long sections of 24" diameter cast iron main. Three of each size saddles (16" and 24") were installed on the cast iron main samples. The cast iron pipe surfaces were prepped, the epoxy bonding adhesive was applied, and then the saddle tees were mounted on the epoxy adhesive. After the epoxy was allowed to cure, and after an initial pressure test was performed to ensure the integrity of the epoxy, drilling and tapping operations were performed on the cast iron main using an ALH System Three pneumatic drilling machine mounted to the bonded saddles.



ALH System Three pneumatic Drilling and Tapping Machine installed on bonded saddle

A total of six (6) drilling and tapping operations were performed: three 4″ NPT threaded taps in the 16″ sample main, and three 5″ NPT threaded taps in the 24″ sample mains. A threaded plug was then installed in each tap. After the plugs were installed and sealed, the bonded saddle tees were capped with blank flanges and were subjected to a 20 psig air pressure test for a minimum of 24 hours. All six (6) test saddles passed the pressure test.

The bonded saddle tee system provides operators with an alternative to consider when performing tapping operations.

The equipment vendor, PLCS, has proposed future testing that could include measuring and quantifying the torque necessary to thread tapped holes in cast iron mains, and directly measuring the maximum torsion strength capacity of the bonded saddles installed on sample cast iron mains by applying external lever torque to the bonded saddles.

Project 5.24.a - Evaluation of PLCS Bonded Saddle Tee is complete and a final report was published for OTD members in February of 2025.

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Alternative Purging Closed Combustion Development

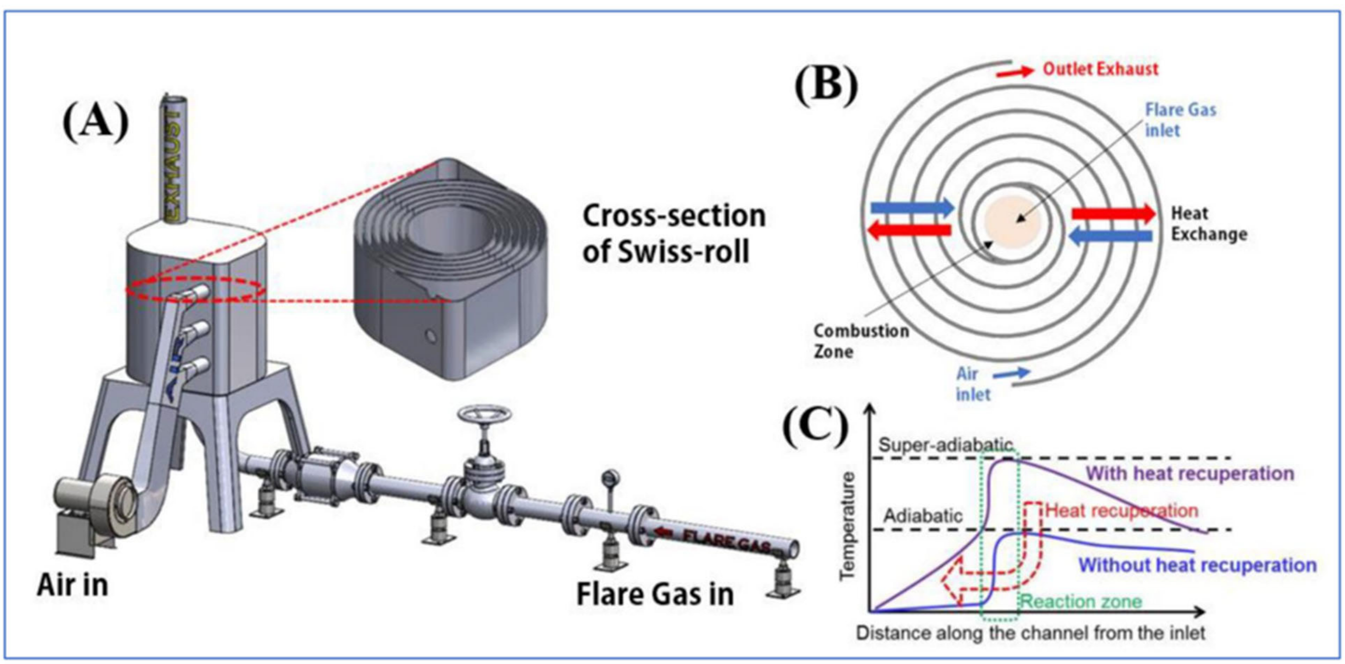
The objective of this project is to develop alternative purging technology. The team will design and test an enclosed combustion control device that can safely and effectively evacuate natural gas from a pipeline. This will reduce methane emissions and customer impact as compared to traditional purging practices.

Project Description

The team will work with a technology provider subcontractor Advanced Cooling Technologies (ACT) on the use of their technology to design a phase-1 prototype combustion chamber that can be used as an alternative to flaring during distribution operations.

A previous project team for project "OTD 5.23.c - Best Purging Practices for Minimizing Methane Emissions" had investigated various alternative purging technologies and found a lack of available products for flaring and safe combustion of natural gas. Flaring equipment is typically made "in-house" and at the job site by the field crews. The project team interviewed Advanced Cooling Technologies (ACT) to obtain information on their technology and its potential use in the industry as an alternative purging method. This project will take the next logical step, working with ACT to further develop the technology to make it available to the industry.

The testing of the prototype will be performed at a pipe farm on a simulated distribution system mock-up operation to vacate natural gas in an 800-foot section of 4-inch PE pipe at an operating pressure of 60 psig. The goal will be to design and test a prototype combustion chamber that can vacate the natural gas in the mock-up pipeline operation in less than 60 minutes. A study and comparison of the technology to a similar flaring operation will be included as part of the project.



Schematic of Swiss roll enclosed combustor for fare gas incineration; (B) Overview of Swiss roll concept; (C) Temperature profiles of the combustor with and without heat recirculation.

Deliverables

Deliverables for this project include a prototype, test results, a comparison to flaring, and a final report.

Benefits

Currently, methane is purged to the atmosphere as part of regulated natural gas pipeline construction and maintenance activities. Avoidance of methane emissions from purging operations have both economic benefits for operators and environmental benefits for the community. The use of combustion technology has the potential to assist in pipeline construction and maintenance activities by providing an economic alternative to purging and flaring that has less customer and environment impact.

Technical Concept & Approach

Specific tasks in this project include:

PROTOTYPE DEVELOPMENT

This task includes all the activities for the prototype design using computational fluid dynamics (CFD) modeling. ACT will create a prototype detail document for review and final approval by the project sponsors (i.e., go/no-go approval). Once final approval is obtained ACT will build and perform preliminary laboratory testing prior to shipping to the pipe farm.

TEST PLAN DEVELOPMENT

This task includes all the activities for developing the test plan, including simulating the jobsite at the pipe farm, reviewing with stakeholders and final approval by the project sponsors.

TESTING OF PROTOTYPE & FLARING COMPARISON

This task includes all the activities for implementing the test plan at the pipe farm. Activities include procurement of needed materials, building out the jobsite pipeline mock-up, connecting, setting up and completion of the test plan.

Results

This project's budget is being used as co-funding for a DOE proposal to FOA 3256, AOI 2b. For this proposal, ACT is the prime recipient. The proposed scope of work will include testing the internal combustor at multiple sites for flaring activities in the field. This proposal was awarded by DOE in December 2024, and the project team plans to resume project work in Q1 2025.

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Operations Technology Development

3-In-1 Electromechanical Gas Ball Valve Testing

The objective of this project is to test a recently developed electromechanically actuated "smart" ball valve that will be installed on the meter set assembly. The project testing will cover industry requirements for destructive, non-destructive testing, ASME B.16.33, and the valve's ability to function as a reliable smart valve for gas service pipe applications.

Project Description

During an emergency or gas release situation one of the safest actions is to immediately stop the flow of the escaping gas and a smart valve can perform this action faster than current manual valve closure practices while providing more information back to the operator on the status of each valve. A smart ball valve provides a quick reliable way to stop the flow of gas and prevent potential negative impacts to customers and improve safety.

This project will include similar testing to what was performed in OTD 5.12.a on the Lorax System pneumatic ball valve solution. The testing will include a survey of all destructive, non-destructive, functional and ASME B16.33 testing that has been performed on the valve during certification. The deliverables will include testing results and recommendations for the electromechanical ball valve applications in gas operations. The project will obtain several production versions of the smart valve, develop a test plan, and implement the test plan.

Deliverables

Deliverables for this project include a test plan, test results, and a final report.

Benefits

A smart ball valve provides a quick reliable way to stop the flow of gas in a potentially hazardous situation and prevent the potential negative impact to customers and improve safety.

Technical Concept & Approach

Specific tasks in this project include:

Develop a Test Plan

A detailed project test plan will be developed and reviewed with sponsors.

Test Production Version of Meter Valve

The task includes all the activities for implementing the test plan to ensure they meet the applicable regulatory requirements. All testing results for the smart valve will be documented along with recommendations on meter set assembly valve (tested version) and potential other versions of the ball valve that include potential curb valve and tee valve.

Results/Status

The project team completed a comprehensive test plan for evaluating the Lorax 3-in-1 electromechanical ball valve and received the two valves for testing. Visual mockups and close-up views of the new valve were documented, but the other valve arrived damaged. Once a replacement valve is received, the team will begin testing according to the established protocol.

Since the Lorax electomechanical ball valve design implements an existing valve that is already certified to ASME B16.33, the project team will review the requirements listed in the standard and verify that the valve has been certified in accordance with these requirements. This verification includes ASME B16.33 standard tests covering dimensional verification, visual inspection, markings compliance, operating indication functionality, shell testing, seat testing, temperature resistance at -20°F and 150°F, and flow capacity/pressure drop analysis. Supplemental non-destructive testing will evaluate operational cycling, 30-day pressure testing at 70°F, continuous thermal cycling, reverse flow performance, battery life testing, LTE-M cellular communications (including sub-2-minute remote disconnect, 25-minute heartbeat monitoring, and 10-year battery life), debris resistance, tamper resistance features (security fasteners, tamper alarms, and cable cut alarms), manual override operation, heat sensor setpoint testing at 65°C, mechanical flood sensor functionality, and remote disconnect capabilities based on LEL levels.

Due to the limited availability of only two valves, destructive testing will be performed last and prioritized in consultation with project sponsors. ASME B16.33 destructive tests include twist, bending, and tensile testing. Supplemental destructive tests will cover 90-day outdoor exposure, chemical resistance, sustained pressure testing, quick burst testing, water intrusion resistance, impact testing, elevated pressure testing, UV exposure, and salt fog corrosion testing.

As stated above, since the Lorax electromechanical ball valve is certified to meet ASME B16.33 requirements, the focus of testing will be on the overall smart safety shutoff system functionality (i.e. the successful closing of the valve when a methane sensor is exposed to natural gas). All other tests that are not already covered in the valve’s already tested certification will be performed after the smart safety shutoff system tests are completed.

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OTD Operations Technology Development

Sensing Water Accumulation in Mains

The objective of this project is to identify sensing technology for water levels in gas mains or siphon drips. The identified sensors will be tested and verified in the laboratory. The sensor testing results and a reference design for a field system will be provided.

Project Description

The project will assess the viability of water level sensing technology suitable for use inside of live gas systems. Drips are intentionally engineered low points installed in natural gas distribution mains to collect condensate and unexpected water infiltration. Drips prevented loss of customer service by providing points where water could collect without blocking the main. Some utilities still have several hundred drips in service; however, water can infiltrate low pressure mains when the water table is high due to weather or water main breaks. A low-cost system is needed that will alert the utility before a critical water level is reached.

A survey of water level sensors will be conducted, and samples procured for bench testing. The current primary candidate is an optical time-of-flight (TOF) sensor that is available off the shelf. The ideal sensor should fit within a ¾" standpipe and be able to measure the water level from above (sensor facing downward into the main). A mockup of a siphon drip will be constructed or procured. This will be operated at ambient pressure with varying levels of water and the sensor data recorded. If these tests are successful, they will be repeated with compressed air to determine any effects pressure may have on accuracy.

Deliverables

Deliverables for this project include an assessment of level sensing/ranging sensors that are commercially available and a summary report on the technologies reviewed, bench testing of the selected sensors in a simulated siphon drip that allows for reasonable variations in water level and pressure, and data analysis and a summary report of the testing results with an assessment of the viability of the sensors. If the sensor passes testing, a reference design for a field prototype will be produced.

Benefits

Routinely checking and pumping out siphon drips on a regular schedule is time consuming, and if not done frequently, may result in loss of customer service. Having advanced knowledge of the water level and its rate of rise would allow operators to schedule resources and mitigate potential outages before they occur.

Technical Concept & Approach

Specific tasks in this project include:

Sensor Identification

The team will review optical time of flight (TOF) range sensors, electromagnetic "radar" range sensor modules, conduct a general review of range/distance sensors, down-select sensors for bench testing, and provide summary report of sensor identification survey.

Sensor Bench Testing

Work in this task includes designing a test chamber for water level sensor that simulates a siphon drip, providing means to introduce or drain water, providing means to pressurize test chamber, designing a fixture to hold sensor under test relative to chamber, performing a series of sensor tests at atmospheric pressure, and performing a series of sensor tests at 0.25 psig and at 0.50 psig.

Data Analysis

The team will capture data from multiple tests and water levels, create a summary report and graphics from the test data, provide a go/no-go assessment for the sensor technology, and create a reference design for a field deployable system based on the testing results.

Results

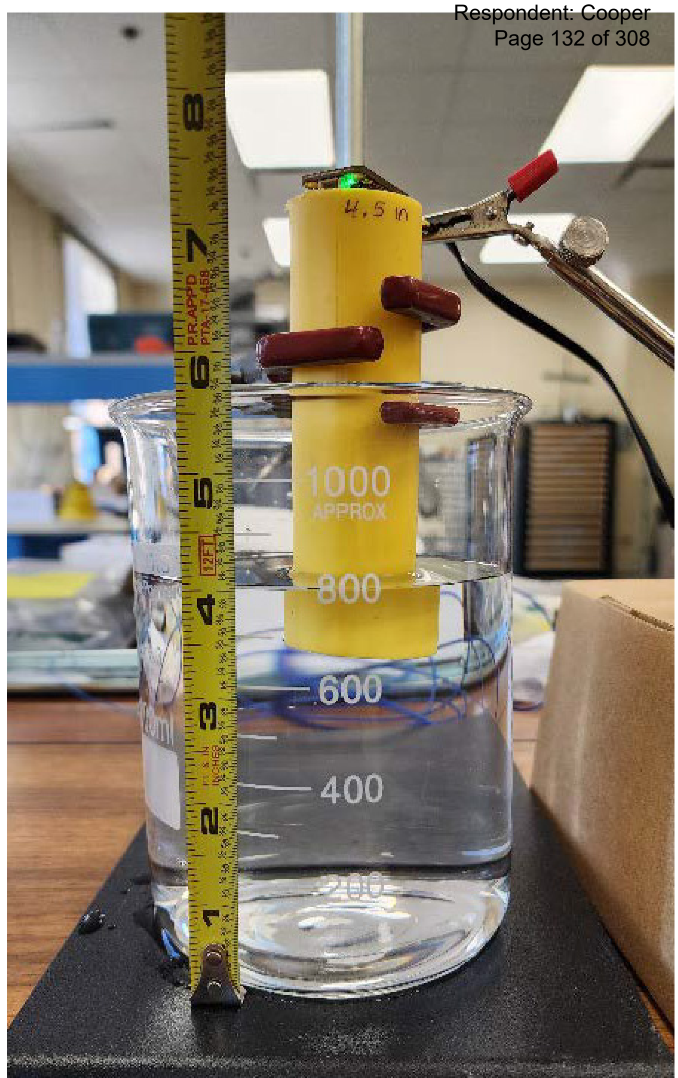
The team identified two time-of-flight (TOF) distance sensors and acquired them for testing during 2024. One is an optical, TOF rangefinder that can measure the distance to a reflecting surface. The sensor sends a pulsed beam of light and measures the time that it takes for reflections to return. The sensor was evaluated with various water heights while aimed down a 1 in. ID pipe. The sensor experiences interference when the spreading light beam intersects the pipe interior. The beam forms a cone of light that spreads with greater distance from the source. The length of the pipe needed to be cut such that the beam could pass without interference. In practice, this type of sensor would need to be positioned near the lower end of the standpipe in a gas utility siphon drip.

The other is a radar sensor that utilizes 60GHz radar technology to detect objects. It operates by emitting a pulsed radar signal that reflects off surfaces. By measuring the time it takes for the signal to return, the sensor determines the distance to the object. This sensor was also evaluated using various water heights while aimed down a 1 in. ID pipe. This sensor experienced interference when the beam intersected the end of the pipe. Therefore, the same cut pipes were used for testing. The sensor was placed at the top of the pipe, 7 in. from the bottom of the beaker and water was gradually added.

Based on testing, the team determined that the light and radar TOF sensors provide a plausible means to measure water level under field conditions. Ultrasonic TOF rangefinders or water pressure sensors will both be influenced by the gas pressure in the main. This pressure will not necessarily be constant over the period of observation and so cannot be calibrated out of the measurement.

The light or radar beams emitted by these sensors spread with distance and will interact with the walls of the standpipe if it is long enough. The positioning of the sensor within the standpipe will need to be considered. There are also lens types for both light and radar beams that can limit the spread. The initial A121 test sensor does not have such a lens.

The radar pulse sensors should be more robust under field conditions. They are more difficult to foul since the emission source is broader than the laser source in the optical version. A small amount of liquid on the sensor would provide a minor peak in the reflection profile with the major peak occurring at the actual liquid surface.



VL53L0X Sensor aimed down 1in ID pipe with 800ml of water.

Status

The team will complete the survey of sensors for this application and compile the results. Based on the findings that optical/radar beams interact with the standpipe walls, additional sensor types will be acquired and tested. Testing of sensors will be conducted in a mock-up of the siphon drip fixture.

The team will reach out to the sponsors to determine if positioning the sensor lower in the access standpipe is acceptable under field conditions. Acoustic sensors are being reconsidered, as they are less sensitive to line pressure variations than originally thought. These may be less sensitive to the length of the standpipe they must work through.

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Product Standards for Plastic Tapping Tees

The objective of this project is to develop a proposed product standard for manufactured tapping tees to ensure that material selection and fitting designs do not potentially lead to premature failure of the fitting.

Project Description

Currently there are no defined product standards that manufactured tapping tees must meet. There are standards for the tees to ensure a certain level of joint integrity, but not for the plastic tee fitting itself. The materials used and the overall design and dimensions of these tapping tees can impact the performance of these fittings. History has shown that improper selection of materials or poor fitting designs can lead to premature failure of the fitting.

One European standard, DIN 1555-3 "Plastics piping systems for the supply of gaseous fuels – Polyethylene – Part 3: Fittings" does address some of the identified product specification needs. The team will reference DIN 1555-3 and other worldwide fitting standards.

Deliverables

Deliverables for this project include a draft tapping tee product standard and a final report.

Benefits

Creating a product standard for conventional heat fusion tees will ensure that the tees uphold certain standards for fitting quality and performance, reducing premature failures.

Technical Concept & Approach

Specific tasks in this project include:

Review Product Standard Needs

The project team will gather and review input/direction from project sponsors and investigate existing tapping tee requirements in North American gas industry standards as well as overseas standards. This information will be used to help identify what tapping tee requirements currently exist and what is still needed as well as possible language that can be used from other types of fitting standards globally.

Develop Product Standard Language

The work in this task includes drafting language for the development of tapping tee product standard(s). The language will be developed and reviewed by the project task team(s) and then reviewed with all of the project sponsors for their comments and input. The team may also reach out to various fitting manufacturers and/or industry SMEs to obtain their input and guidance regarding tapping tee product standards.

Results/Status

The project team developed and sent a survey to sponsors to gather information on tapping-tees. Survey responses have been received, and the team is analyzing the survey data.

The team reviewed various standards and industry papers, and industry publications. The team will compile a list of gaps in current standards to send to the sponsors for review.

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OTD Operations Technology Development

Individual Packing Requirement for all Bulk Packaged Plastic Fittings

The objective of this project is to identify the proper fitting standard (or standards) and develop the appropriate language to incorporate a requirement to have individual wrappings on all plastic fittings inside a bulk package into the existing ASTM standard(s).

Project Description

The objective of this project is to identify the proper fitting standard (or standards) and develop the appropriate language to incorporate a requirement to have individual wrappings on all plastic fittings inside a bulk package into the existing ASTM standard(s). Currently there is no mandatory requirement for plastic fittings to be packaged individually when provided in "bulk" packaging. Bulk packaging refers to the practice of selling products in large quantities, such as in bags, boxes, or cases. Prior industry analysis of joint integrity has shown that it is critical to have clean properly prepared surfaces on both the pipe and fitting prior to joining.

Joining polyethylene (PE) pipe is a fundamental activity performed by every gas utility across the country. Regulators and utilities are looking to enhance the integrity of PE fusions. Although the failure rate for PE fusions is quite low, the consequences from these limited failures can be significant.

Typically, smaller diameter fittings are supplied in bulk and are housed in bags without the fittings being individually bagged. Once the bulk packaging is opened and all of the contents are exposed to the elements, there is a potentially increased chance of contaminating the fittings and/or misplacing some of the fitting components (i.e., o-rings and fasteners). Good fusion procedures generally require keeping the fitting in its bag until it is ready to be attached to the pipe and fused. Requiring each fitting to be bagged individually will protect them from being exposed to the elements.

Deliverables

Deliverables for this project include a review of existing standards and other information found on packaging, draft language for incorporation into existing ASTM standards including multiple revisions incorporating stakeholder feedback, and a final report.

Benefits

Requiring individual wrapping of all products, even bulk packaged fittings, will improve overall system integrity by reducing the risk of fitting contamination and/or displaced fitting components.

Technical Concept & Approach

Specific tasks in this project include:

Review Packaging Needs and Existing Standards

The project team will gather and review input/direction from project sponsors and investigate packaging requirements in North American gas industry standards as well as overseas standards. This information will be used to help identify which ASTM standards require modification and possible language that should be incorporated into the current industry fitting standards.

The findings on existing standards and other information found on packaging will be reviewed with the project sponsors prior to moving forward with developing new packaging language.

Bulk packaged tapping tees – not individually wrapped

Develop Packaging Requirements Language

The work in this task includes drafting language for incorporation into existing ASTM standards. The language will be reviewed with the project sponsors for their comments and input. The team may also reach out to various fitting manufacturers to obtain their input and guidance regarding packaging requirements.

Revisions to ASTM Standard(s)

The work in this task includes taking the results of the previous task and establishing a task group to implement the required language within the appropriate ASTM standard(s). Since ASTM is a consensus-based organization, it may take multiple iterations and/or revisions to the language to implement the proposed changes. It is possible that the proposed changes to ASTM standards may require more time to reach consensus.

Results/Status

In 2024, the project team identified and reviewed packaging requirements in ASTM and other worldwide plastic component standards. The team identified DIN (European standard) containing packaging language in their plastics component standard and reviewed it for possible incorporation into ASTM D2513. The team also reviewed the past "bulk packaging" ASTM project ballot and contacted ASTM members who previously cast negative votes on the ballot.

Bulk package containing individually wrapped fittings

The team created a new draft language (new "packaging" section to be included in ASTM D2513) for consideration for a new ASTM ballot. A meeting was held with project sponsors to make final changes before re-balloting it to ASTM in September 2024. The team reviewed all the comments and determined if they were valid and/or if changes should be made to the "packaging" section. The team then assembled all the replies and comments and developed responses. In 2025, the team will meet with the ASTM voters and the OTD project sponsors to address the comments, stress the need for individual packaging of plastic components, and re-ballot to ASTM.

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OTD Operations Technology Development

Hydrogen Blending Pilot Gas Quality Evaluation and System Modeling

The objective of this project is to conduct hydrogen measurements at various locations to evaluate hydrogen dispersion post-injection. The data will be compared to results from existing system simulation models and determine if model updates are needed to accommodate hydrogen blending.

Project Description

The project team will conduct hydrogen percentage and fuel property measurements (heating value, Wobbe Index, density, temperature, etc.) at 14 locations throughout the hydrogen blending pilot area to evaluate hydrogen dispersion under dynamic conditions. In-line sensors will be installed to enable continuous measurement of hydrogen concentrations at 4 locations. A portable gas analyzer will be utilized to obtain hydrogen measurements at 10 other locations. The data will then be compared to results from existing system simulation models and determine if model updates are needed to accommodate hydrogen blending. A year's worth of field data will be collected to evaluate any dispersion behavior differences with seasonal demand changes.

Deliverables

Deliverables for this project will include a data collection plan, field testing data, system modeling evaluation findings, documented recommendations on any modifications needed for existing system simulation models when transporting hydrogen blends, and a final report.

Benefits

This project will help understand the extent and travel time of hydrogen after injection into gas systems to support system forecasting and evaluate any potential customer billing impacts when blending in an interconnected distribution system.

Technical Concept & Approach

Specific tasks in this project include:

Data Collection Plan Development and Testing Set-Up

The work in this task includes developing the data collection plan that will be used for field testing. This task will also involve procurement of in-line sensors, data logging equipment, and a portable analyzer to be used for field testing. The project team will install sensors and data loggers to measure hydrogen levels in various locations within the pilot area.

Mobile Gas Analyzer to be Used for Validation Testing (Source: Bright Sensors)

Test Stand for Thermoelectric Generator

Field Testing

The project team will continuously collect data from the in-line sensors installed. The project team will also conduct validation field testing using a portable analyzer. The plan is to conduct 4 validation tests (once per quarter) to account for seasonal variations.

Gas System Modeling and Data Analysis

The work in this task includes reviewing the existing system model and simulating hydrogen dispersion after injection into the gas system under dynamic conditions. Results will be compared to field testing data to determine if existing simulations need to be modified for hydrogen blending operations to forecast hydrogen extents and potential impacts to system forecasting and customer billing.

Results

The project was kicked off in January 2024. Fourteen test locations were selected for gas quality checking (four locations for continuous testing and ten locations for manual quarterly testing). The location selection's intent was to spread out data collection sites to cover a wide landscape of the city. In addition to the gas quality checks across the city, other data is also be collected, including gas composition, electrolyzer performance (water usage, efficiency, etc.), hydrogen blending rates, natural gas flowrates, and gas usage rates at the testing locations.

Since the kick-off, the project team has conducted a review of technical and economic specifications for hydrogen sensors that can be utilized for the project. The project team ultimately selected the H2Scan HY-OPTIMA sensor for the project. Given that there is no reasonable way to power cycle the sensors to conserve power and obtain accurate and timely results, the continuous monitoring sites will require on-site power.

This change in site criteria led to re-evaluation of testing location candidates. The H2Scan gas sensors also need to see regular gas flow, and sample gases cannot be vented to atmosphere at the test locations. Given these constraints, installing a thermal-electric generator at test locations would address these concerns, providing both power and flow. The team procured a thermal electric generator and built a test rig for in-house testing of the generator, sensor, and data acquisition system prior to field deployment. Initial field testing is planned for June 2025.

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OTD Operations Technology Development

Field Pilot of Real-Time Pipeline Threat Detection System (SPADE System)

The objective of this project is to demonstrate the SPADE real-time detection technology for detecting mechanical threats to steel pipeline systems.

Project Description

SPADE has developed and patented a technology that will detect and alert pipeline operators of mechanical impacts to their rectified steel pipelines, based on monitoring the cathodic protection current. SPADE is able to discriminate impacts by type of aggression, such as mechanical impact, pipeline/casing electrical short, illegal tapping, lightning strike, etc. Steel pipeline rectifier systems are instrumented with a data acquisition module for continuously monitoring the electric currents applied by the CP system. Changes in the rectifier current signal are analyzed directly at the cathodic protection rectifier where SPADE is installed.

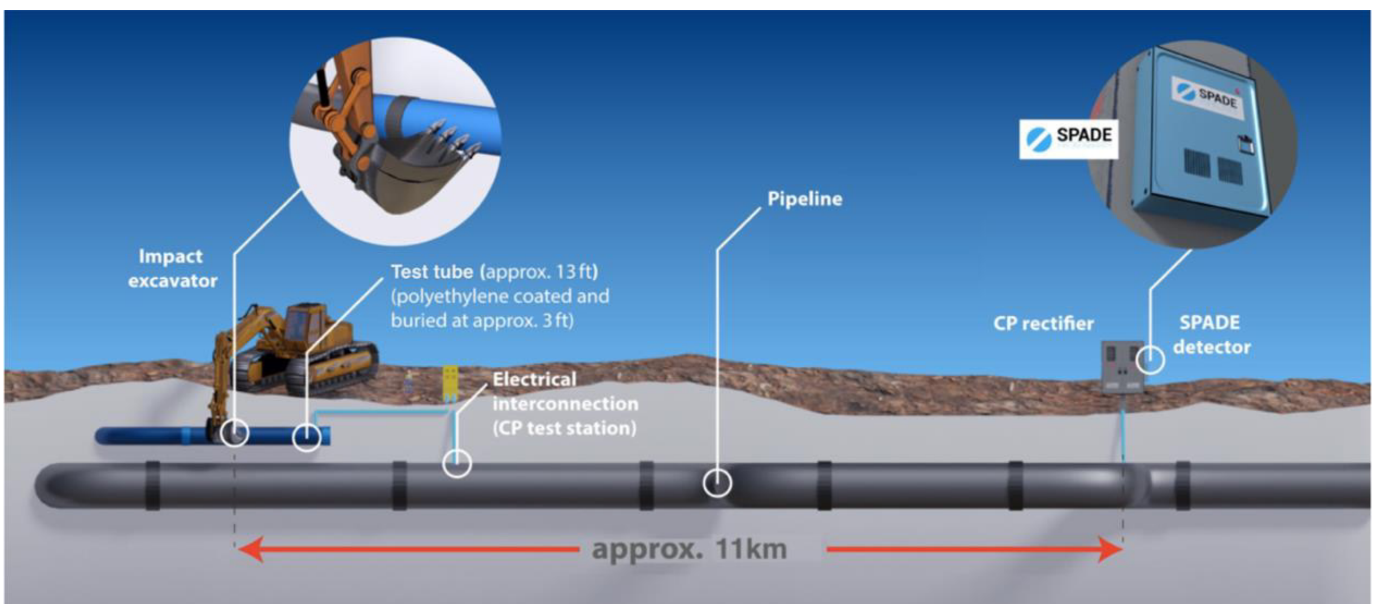
SPADE installed and is monitoring six total SPADE units on an operator's transmission system. Included in the scope is reporting and interpreting of the signals, training of operator personnel, as well as maintenance of hardware and software.

Deliverables

Deliverables for this project will include installation, maintenance, reporting and training; full documentation including data, results, conclusions, and recommendations; a Webinar with the SPADE company and funders of this project; and a final report.

Benefits

The SPADE technology provides operators with real-time intelligence and awareness of mechanical threats that occur to their rectified steel pipelines. Detectable threats include third party hits and shorted casings. This technology allows operators to respond to threats sooner and with greater geo-locational accuracy reducing risk.



Schematic of the SPADE pilot at GRTgaz. Real-time detection of excavator impact was achieved.

Photo of installed SPADE demonstrator

Technical Concept & Approach

Specific tasks in this project include:

SPADE Installation and testing on an operator's pipelines

SPADE is supplying and installing the system, including required hardware, for detecting mechanical impact on two rectified transmission pipelines. The SPADE industrial unit, to be installed at each site, has the following features: an industrial-rated weatherproof-enclosed computing module for digital signal monitoring and processing, and a cellular GSM modem for data transmission that can also be adapted for satellite communication.

Monitor the System

Monitor the alarm response of the SPADE systems at each site. This task will include monitoring data from each SPADE system on an hourly or daily basis as appropriate with the objective of sending a real-time alert within 2-5 seconds when a mechanical damage occurs on an in-service pipeline, development of SPADE algorithms to support monitoring data, identification of any false negative or false positive indications, and training on monitoring using the SPADE systems (half-day total).

Photo of SPADE demonstrator

Alarm Response

Report, interpret, and explain to company personnel the alarm responses of the SPADE system at each site. This task will include reporting to company personnel within 24 hours any alarm responses of the SPADE systems, interpreting and explaining to company personnel the data received that led to alarms and, based on the signals received, identify the cause of any alarms. Training on interpretation of SPADE signals and identifying signals that lead to alarms will also be provided (half-day total).

System Maintenance

Maintain the installed SPADE systems for the duration of this project with monthly (or more frequently if necessary) on-site field inspections and any necessary maintenance and troubleshooting. The maintenance will include algorithm updates. Training focused on the knowledge and tools required to manage and maintain the SPADE systems will be provided as needed.

Results/Status

The project was initiated. SPADE has installed and configured sixSPADE units. SPADE is currently monitoring signals. On-site checks of network connectivity and telemetry were conducted, and low cell signal was noted in a couple of areas. SPADE began remote monitoring of data streams from the installed units.

SPADE will be finalizing, installing, and configuring the SMS/Email alert notification system. SPADE is also finalizing their web-based user interface and device management system.

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OTD Operations Technology Development

Ultrasonic Meter Testing – Landis & Gyr with Honeywell Added

The objective of this project is to conduct evaluations of recently introduced Landis & Gyr G480 and Honeywell AC NXU ultrasonic residential 250 class gas meters for gas utility and State Commission acceptance.

Project Description

This project will evaluate the accuracy of the meter metrology, long-term performance, compliance with meter standards, and smart shut-off capabilities of the Landis & Gyr G480 and Honeywell AC NXU 250 ultrasonic residential gas meters. The majority of the tests on the approved test plan will adhere to ANSI B109.6 – Single Path Ultrasonic Meters, however not every test from ANSI B109.6 is included in the test plan. The remaining tests in the test plan are from DIN EN 14236 – Ultrasonic Domestic Gas Meters, OIML R137 – Gas Meters, or are GTI Energy developed tests.

Deliverables

Deliverables for this project will include collected data results and analysis, peer reviews, sponsor reviews, and a final report.

Benefits

Evaluation of the new Landis and Gyr G480 and Honeywell AC NXU 250 ultrasonic residential gas meters will provide objective performance comparison data for LDCs to evaluate against other ultrasonic meters they may be considering. This type of independent evaluation is often required for regulatory approval for use of these types of gas meters. Evaluating the effectiveness and performance of these meters may increase market adoption of ultrasonic meter technology.

Pilot Flow Accuracy Test Rig

Technical Concept & Approach

Specific tasks in this project include:

Metrology Testing

The work in this task includes both short-term and long-term metrology testing. The long-term metrology test will be conducted for 6 months on an outdoor test rig to evaluate these meters under the Summer and Winter weather conditions. Additionally, there will be tests involving the evaluation of the ultrasonic sensors at extreme temperatures, humidity and with impurities.

Smart Meter Testing

The work in this task will include conducting multiple tests on the effectiveness of the shut-off valve and other integrated safety features. These tests will be performed at various pressure and flow rates to evaluate the performance of the shut-off at these conditions. Additionally, testing will be performed to evaluate the range/performance of the communication of these new meters. Lastly, testing will be performed to validate that these smart devices will shut off when an excess flow or other critical levels are present.

Data Analysis

The work in this task includes analyzing the data

Outdoor Accelerated Life Test Rig

Meter Capacity Test Rig

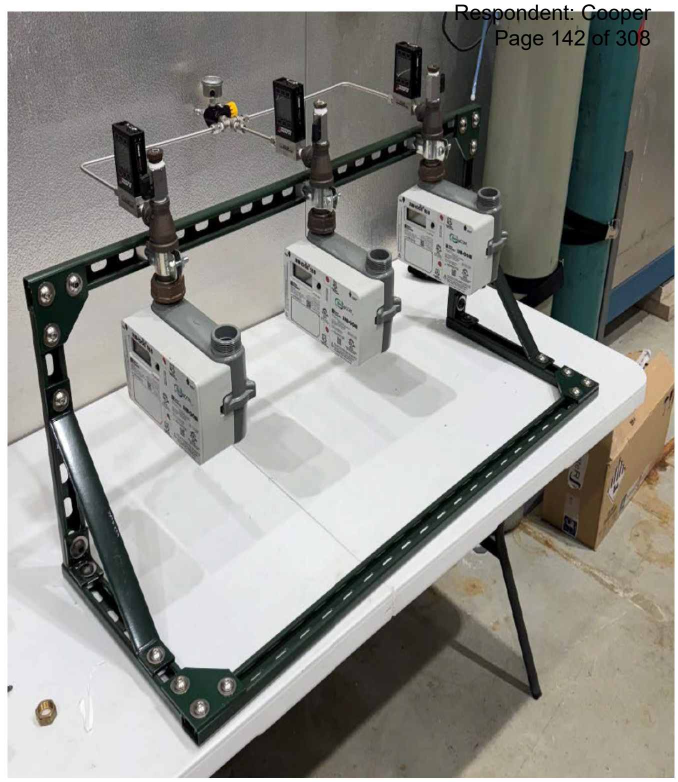
Humidity Test Rig

obtained during the previous two tasks as well as preparing the data to be included in the draft final and final reports.

Results/Status

The team received 9 Landis+Gyr G480 ultrasonic residential gas meters and received training from Landis+Gyr employees on how to operate these meters. They have begun the planned metrology, special metrology, and shut-off valve testing on these meters.

The team developed custom testing rigs to perform the tests as described in the respective codes and standards. The Meter Capacity Test Rig was required to measure the flow rate at a known pressure drop across the meter. The Pilot Flow Accuracy Test Rig was required to supply air at a constant flow rate of approximately 0.25 CFH to evaluate the meter's ability to read low flow rates. The Relative Humidity Test Rig was required to be a closed flow loop within a chemical chamber to produce a consistent relative humidity using a specific chemical saturation. Finally, the Shut-off Valve Leak Test Rig



Shut-off Valve Leak Rig (outside of Temperature Chamber)

was required to supply a constant pressure of air to the inlet of the meters and use mass flow meters to record the leak rate of the valve over a 24-hour period.

The project team performed the Initial Accuracy test (ANSI B109.6 – Section 3.3.1) and the Meter Capacity Test (ANSI B109.6 – Section 3.2.1.2) on all nine Landis+Gyr G480 meters and tested three of these meters per the Pilot Flow Accuracy Test (ANSI B109.6 – Section 3.12.B.8), which were thenstarted on the six-month Outdoor Accelerated Life Test (ANSI B109.6 –Section 3.3.3).

The team also tested two Landis+Gyr G480 ultrasonic residential gas meters per the Resistance to Water Vapor Test (DIN EN 14236 – Section 6.12) and three more of the Landis+Gyr G480 ultrasonic residential gas meters per the Shut-off Valve – Leak Test (DIN EN 16314 - Section 7.13.4.5).

The project team will complete the remaining testing on the Landis+Gyr G480 ultrasonic residential gas meters during the second quarter of 2025, with the testing on the Honeywell AC NXU ultrasonic residential gas meters expected to be completed by the end of the third quarter of 2025.

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Operations Technology Development

Development and validation of a plastic gas pipe tensile load measurement device

The objective of this project is to build and field test a prototype load measuring device which will help operators ensure that plastic pipe did not exceed the manufacturers specified maximum tensile load during trenchless pullback.

Project Description

This project will test a prototype, demonstrate the prototype in the field, and support commercialization of a plastic tow tension measurement device that will measure and record in real time the tensile stresses that are being applied to plastic pipe during the pull-back process for trenchless installations. The device will be attached in the proximity of the weak link during the pull back process.

Deliverables

Deliverables for this project will include a draft test plan, a field ready prototype for testing, a field demonstration and documented feedback, a commercialized product ready for market, and a final report.

Benefits

The ability to measure, display, and record tensile stresses for plastic pipe during trenchless pull back installations in real time can confirm that the plastic pipe is safe and did not exceed the manufacturers specified maximum tensile load. The device can also provide an accurate traceable record of the tension load during the pullback process.

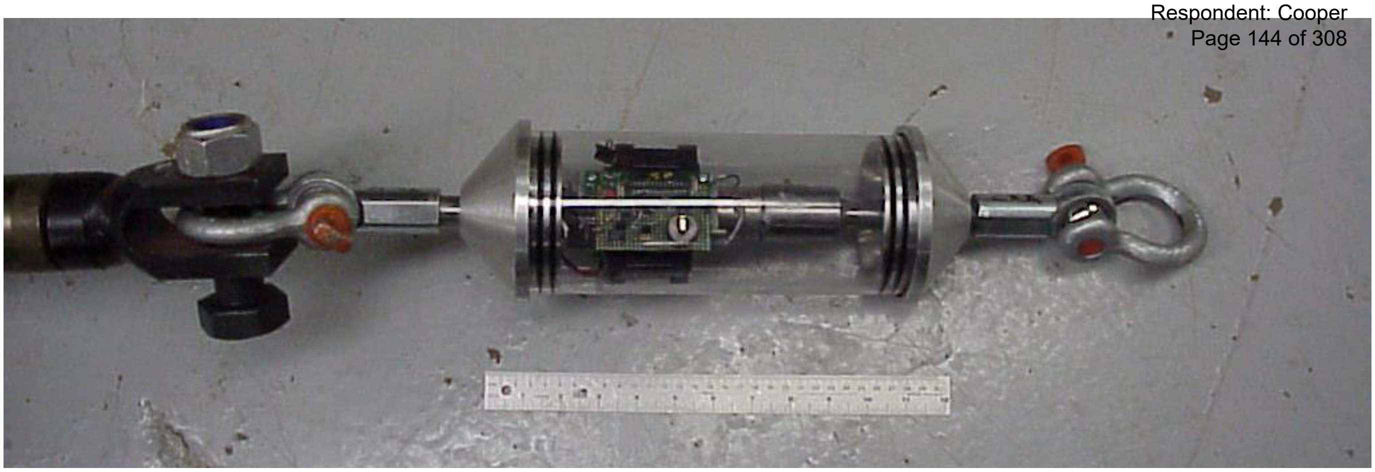
Technical Concept & Approach

Specific tasks in this project include:

Creation of a Prototype & Test Plan

The project team will create a prototype of the plastic pipe load measurement device. The prototype details will be finalized during review meetings with OTD members. A demonstration and test plan of the prototype will be created and approved by sponsors.

Photos from past field demonstrations of the device can be seen below:



Field Demonstrations of Prototype

The project team will coordinate a minimum of (3) field demonstrations of the prototype. The test plan will be implemented, and the results will be documented.

Commercialization

The project team will work with industry experts to support the commercialization of a final product for industry use. Agreements and contracts will work to benefit OTD members for project sponsorship.

Results/Status

This project is on hold. The planned prototype developer is not available and the product team has meetings planned with other developers.

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Hydrogen Live Work Equipment Compatibility Investigation

The objective of this project is to evaluate and test the operation compatibility of "live work" natural gas equipment, tooling and procedures with a natural gas network re-purposed to dedicated 100% hydrogen operation in the future.

Project Description

Operators need to verify if their existing tooling, equipment, and procedures that were designed for working with live (pressurized and present) natural gas are compatible with future re-purposed dedicated pure hydrogen pipelines. This proposed project will include a discussion on how to determine which "live work" activities to include. Removing doubts about the need for changes to operating procedures and possibly tools and equipment used with 100% hydrogen will let manufacturers know if new products need to be brought to market.

Deliverables

Deliverables for this project will include a documented list of equipment to be tested, a detailed test plan and test rig hardware, test results and findings from laboratory testing with recommendations, and a final report.

Benefits

To maximize availability and minimize downtime of repurposed natural gas pipelines in dedicated hydrogen service, operators would benefit from continuing to use traditional "live work" natural gas tooling, equipment, and procedures for maintenance without interrupting gas flow.An example of a common and critical "live work" procedure is hot tapping equipment, however it is unknown whether existing natural gas tooling, equipment, and documented procedures are compatible with hydrogen service.

Technical Concept & Approach

Specific tasks in this project include:

Identify and Evaluate Equipment and Procedures for Hydrogen Impact

The project team will apply the guidance from OTD member SMEs to determine the specific "live work" procedures to investigate, as well as the suppliers of those tools, equipment, devices. The areas of concern for pure hydrogen compatibility will be explored and identified for each of the scenarios selected.

Develop Test Plan & Test Rig

Based on the findings on the evaluation of equipment and with collaborative input from the supplier/manufacturer of the equipment, tool, or device being evaluated, a specific test plan will be developed. The test plans will include a determination of the most appropriate scale and location for conducting the test. If a piece of equipment, tool, or device identified does not require testing to provide sufficient confidence in its compatibility, then written documentation, modeling results, or other products will be the deliverable.

Conduct Testing and Data Analysis

Lab testing will be conducted, and data/learnings will be collected and documented. The findings will be analyzed, and additional testing will take place until development of recommendations on any changes needed to equipment, tooling, or procedures can be prepared.

Results

The project team met with sponsors to confirm the scope will be limited to tapping and stopping equipment and testing on 6" steel and plastic pipe at defined pressures. The sponsors also identified which equipment manufacturers GTI Energy should reach out to. The team has begun meeting with those manufacturers of tapping and stopping equipment to discuss hydrogen compatibility of their equipment and their interest in participating in a testing and evaluation project with GTI Energy. Once a partner is identified, the team will begin developing a test plan along with a budget and schedule.

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De-blending Demonstration

The objective of this project is to complete a feasibility study on the installation and demonstration of a de-blending technology in a closed-loop system to evaluate performance and operations under various operating conditions.

Project Description

This project will perform a feasibility study on the installation and demonstration of a deblending system. The proposed demonstration was to evaluate system performance under various seasonal and operating conditions (e.g., various hydrogen blends, ambient temperatures). System data will be continuously collected to support the development of recommended practices for operating and maintaining deblending systems for large-scale hydrogen blending in natural gas distribution.

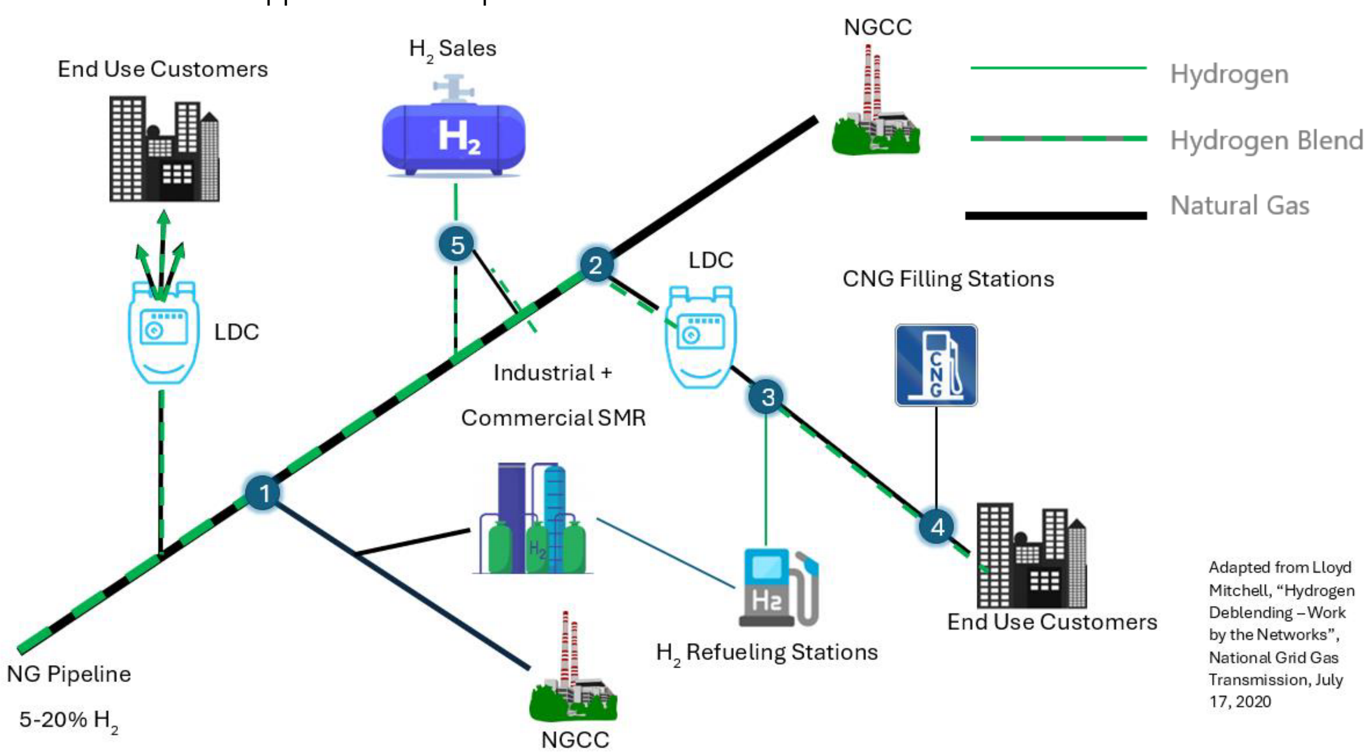
Deliverables

The project deliverables include a rough layout of closed loop demonstration system, a list of equipment needed and cost estimate, and a final report containing the findings of the feasibility study, hydrogen blending thresholds (e.g., up to 20 vol%), operating parameters (flow and pressure), and data to be collected to support the development of deblending system practices.

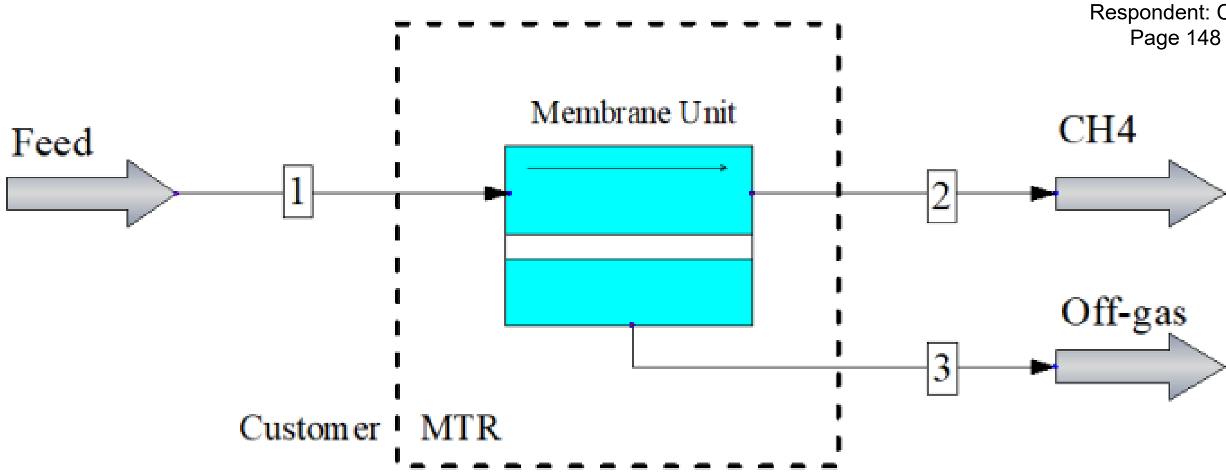
Benefits

As gas utilities are exploring hydrogen blending into natural gas infrastructure to reduce greenhouse gas emissions, it is critical to address potential impacts on downstream users who may be adversely affected by elevated hydrogen concentrations in their gas supplies. Certain end-users (e.g., CNG filling stations, liquefied natural gas (LNG) peak shaving plants, and steel and glass manufacturers) have strict gas quality requirements and may face significant operational challenges with hydrogen. Example concerns are partial liquefaction, malfunction or degradation of burners, reduced heat transfer, and increased moisture content or emissions. These concerns can compromise equipment and process safety.

Hydrogen separation (deblending) technologies have the potential to protect these sensitive



Potential Deployment of De-blending Technologies in a Gas System Transporting Hydrogen Blends



Simplified Process Flow Diagram of the De-blending System

end-users. These technologies can selectively remove hydrogen from a hydrogen-natural gas blend, allowing gas utilities to deliver hydrogen blends to most end-users while still providing near hydrogen-free gas to sensitive end-users with strict gas quality requirements. In addition, deblending technologies can support hydrogen delivery systems for end-use applications such as hydrogen refueling stations or fuel cells. This dual approach has the potential to enhance the flexibility and resiliency of future gas systems.

Technical Concept & Approach

Specific tasks in this project include:

Gathering Data for Design, Construction, and Commissioning

The work in this task included collaborating with the deblending technology provider and an engineering and construction firm to design and integrate a deblending technology in a closed loop system at GTI Energy. The deblending technology provider provided a skid-mounted system. The GTI Energy project team worked with an engineering and construction firm to install and commission the deblending system at GTI Energy (e.g., foundation, process connections, assembly and installation of interconnecting piping, insulation).

Demonstration

Once commissioned, the deblending system will undergo a 12-month evaluation. Data will be collected on system performance and operations (e.g., deblending efficacy, power consumption, maintenance frequency). The intent is to conduct the demonstration for 12 months to evaluate how operations may differ with various seasons and hydrogen blends over time.

Data Analysis

As the demonstration is in progress, system performance data will be continuously collected. The project team will analyze the data to determine if there are any performance differences as ambient temperatures change. Data findings and lessons learned will be utilized to develop recommended practices for operating and maintaining a deblending system.

Results/Status

The project team finalized the specifications and data collection items to be used for designing the test system. The test system assumed a Compressed Natural Gas (CNG) station usage scenario and a 20% hydrogen-natural gas blend being supplied.

The data collection plan includes: continuous monitoring of power, pressure, flow, temperature, the composition of inlet and outlet streams to determine deblending efficacy, leakage detection, system downtime, hydrogen losses if any, and heating value measurement of gas streams entering and exiting the deblending system.

The project team obtained quotes from two de-blending technology manufacturers and two engineering and construction firms to support the design, construction, and commissioning of the test loop. These quotes were utilized for the project feasibility analysis.

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OTD Operations Technology Development

Development of a Low Cost Hydrogen Sensor for in-pipeline application

The objective of this project is to develop a high accuracy low-cost hydrogen sensor to detect 0% to 100% hydrogen concentrations.

Project Description

The goal of this project is to develop a low-cost hydrogen sensor in a wide measurement range (0%- 100% H2 in NG), with relatively high accuracy (<0.5%). The team will evaluate existing commercial H2 sensors and compare their performances, develop and test an inexpensive optical sensor for measuring H2 with 0.5% accuracy and H2 concentrations ranging from 0% to 100%, configure fuel mixture properties using existing data, and demonstrate the sensor prototype in at least two OTD member sites.

Deliverables

Deliverables of this project include a summary of existing commercially available H2 sensors, development of an inexpensive non-intrusive sensor that can detect a wide range of H2 blends with high accuracy, and a final report.

Benefits

This project will provide optionality in selecting hydrogen sensors and a lower cost product to consider. This optical sensor capability can also be expanded to detect other gas species, including methane, propane, ethane, etc.

Technical Concept & Approach

Specific tasks in this project include:

Sensor Design and Optimization

The work in this task includes purchasing materials for sensor design and optimization, conducting sensor design and optimization, testing sensor performance, and troubleshooting.

Sensor Field Testing

The work in this task includes coordinating with two OTD members on sensor demonstrations, traveling to field sites for sensor installations, results analysis, and troubleshooting.

Fuel Properties Analysis and Report

The work in this task includes a summary of historical fuel mixture properties test results, data analysis of sensor testing results, and reporting on sensor performance.

Results/Status

The project team and the UW-Madison team worked together to finalize the sensor prototype configuration and testing conditions.

The project team will select field demonstration sites, continue to coordinate with selected OTD member sites for sensor prototype testing, and purchase parts needed for experiments.

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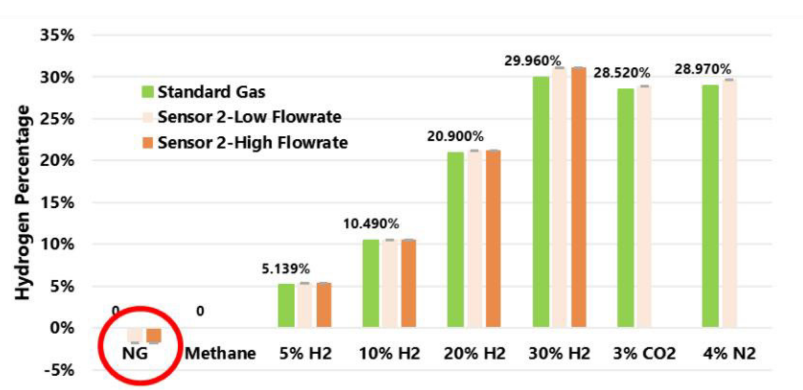


OTD Operations Technology Development

Community Geothermal Systems - Opportunities for LDCs to Consider

The objective of this project is to develop a white paper on Community Geothermal Systems (CGS) to help LDC's investigate the potential opportunities and risks when considering the implementation of CGS (heating and cooling).

Project Description

The team will help OTD members better understand the opportunities and risks associated with community geothermal systems as well as investigate and report on current and planned CGS pilots (utility involved projects and stand-alone projects). Part of the investigation will include the identification of synergies that may exist within the materials of construction and operations of the existing natural gas piping infrastructure and a network serving a CGS. The team will create a white paper on community geothermal systems to assist in the knowledge transfer. In addition, the team envisions creating and/or participate in an existing utility collaborative focused on community geothermal systems.

Deliverables

Deliverables for this project will include available CGS information, a draft white paper, and a final report.

Benefits

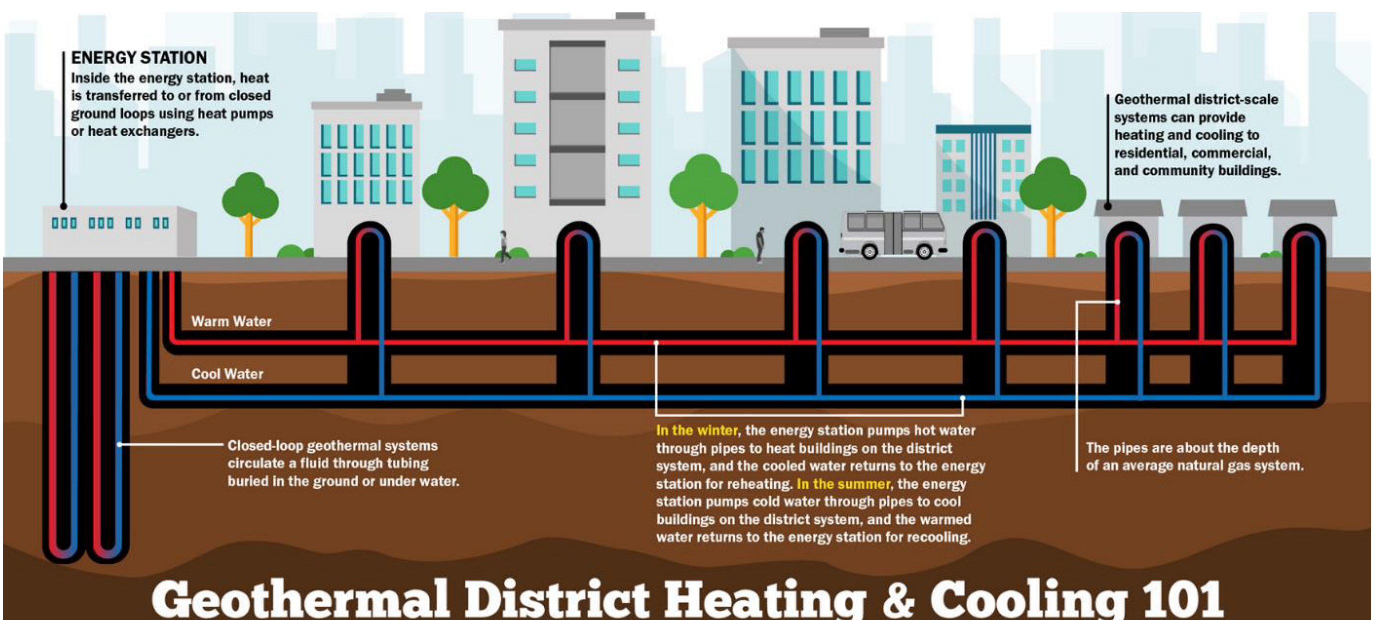
Community distributed geothermal energy offers a decarbonization approach with synergies to LDC operations and infrastructure. These systems may align with state electrification policies and available grants for supporting decarbonization efforts. Community geothermal systems can reduce energy costs for customers and boost energy resilience in local communities.

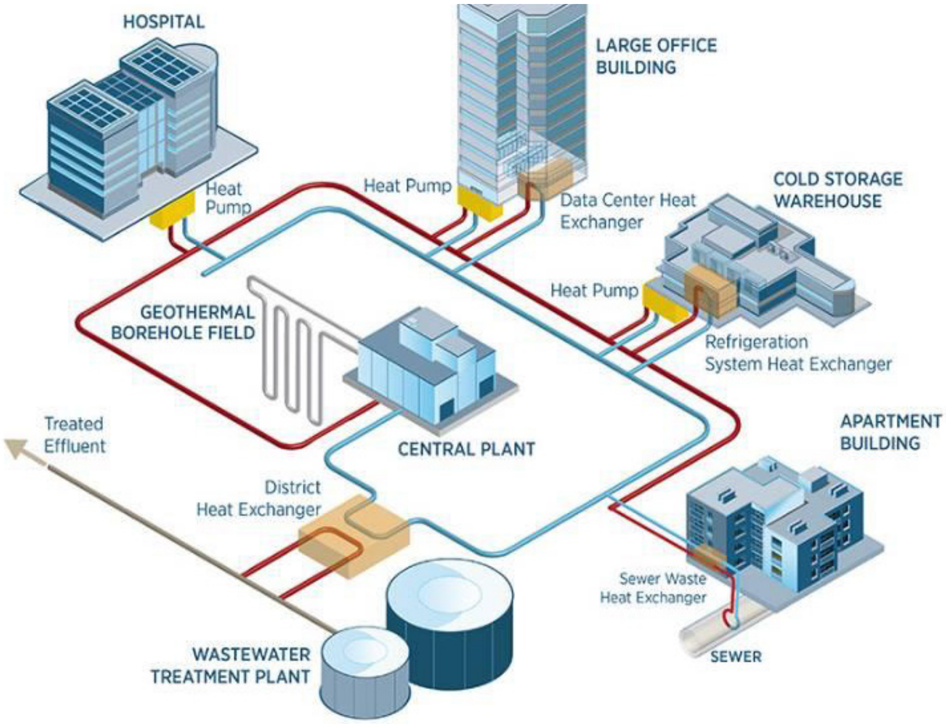
Technical Concept & Approach

Specific tasks in this project include:

Review and Capture Information on CGS

The project team will gather input from project sponsors and investigate the existing geothermal marketplace including service providers and project archetypes. This task will explore emerging community scale projects in the U.S. and Canada, including policy and market drivers, planning, feasibility studies, technical design, economics, and results as available. The team will identify common materials and operating systems that could be repurposed for CGS applications and explore European best practices. The team will also examine the role of LDCs in these systems.





Depiction of one possible community geothermal system

Develop CGS White Paper

This task includes drafting a white paper on community geothermal systems to provide information to project sponsors on these systems, case studies, decarbonization benefits, and potential opportunities and risks for LDCs. The white paper will include a high-level feasibility analysis, cost outline, synergies between natural gas infrastructure and CGS networks, and conversion opportunities for existing district systems.

CGS Discussion Group

This task includes developing a CGS discussion group that will meet periodically to discuss community geothermal systems topics, review pilot projects, share lessons learned, and feature guest speakers.

Results

The project team determined the key topics for the white paper and began collecting information on planned or existing geothermal pilot projects, legislation, regulations, incentives, and market drivers. Key white paper topics include regulatory policy and legislation impact, technology and system design, site selection, cost effectiveness, business model considerations, and available resources.

The team attended the New York Geothermal Energy Organization Fall 2024 conference, focusing on the Thermal Energy Network track and Incentives & Financing track. During the conference, the team visited a New York City Housing Authority (NYCHA) project site utilizing geothermal energy for domestic hot water production, gathering valuable data and lessons learned.

The team joined the Utility Networked Geothermal Collaborative, a discussion group consisting of representatives from gas utilities and industry members, and is leading the Innovation Working Group. Through this working group, the team has engaged geothermal technology vendors and discussed needs for validation of technologies claiming to lower costs and installation time for geothermal loops or manifolds.

Key barriers to utility-led geothermal installations were identified, including initial cost recovery challenges and split-ownership requirements under IRS Section 48 tax incentive rules. The team identified several areas for future investigation, including heat transfer fluid improvements, environmental impacts to open loop systems, avoided cost analysis, workforce development opportunities, and modeling impacts of electrification on gas utilities.

Status

The team is continuing to gather data on geothermal projects and white paper topics and developing the white paper.

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OTD Operations Technology Development

Acoustic Leak Detection Sensors

The objective of this project is to initiate an investigation and analysis of Acoustic Array handheld instruments for the purpose of leak detection on aboveground gas distribution system elements.

Project Description

This project will conduct an initial review of the market to determine core vendors and product solutions. The performance specifications will be reviewed to formulate a better understanding of detection limits and expectations. A leak detection test will be conducted in the laboratory to demonstrate leak detections for a range of gas pressures and leak rates.

Deliverables

Deliverables for this project will include a market review of the sensors, an evaluation on the sensor technology with results, conclusions, and recommendations and a final report.

Benefits

The use of Acoustic Array leak detection instruments may be of importance to detect high pressure leaks on aboveground system components and may have increased sensitivity to help better detect leaks on hydrogen pipe segments. These can reportedly detect leaks from high pressure pipe from a safe standoff distance, reducing the risk to field personnel, and may also allow for more rapid scanning of complex aboveground systems.

Technical Concept & Approach

Specific tasks in this project include:

Market/Product Review

The project team will conduct a literature review and market survey of commercially available acoustic leak detection devices. This will include cost, features, acoustic range, pressures, etc.

Laboratory Testing/Technology Evaluation

The team will acquire 1-2 acoustic devices, either by purchasing or loaning, to conduct laboratory testing. Some variables that will be tested and observed include the ability to detect, locate, and quantify leaks. The team will conduct testing onsite in controlled aboveground leak scenarios.

Data Analysis

The team will analyze the data from laboratory testing to determine the performance and detection capabilities of acoustic leak detection devices.

Results/Status

The project team discussed background information on acoustic leak detection technology, the industry need and business value, the project scope and objectives. Training and a field demonstration were performed using an acoustic leak detector device.

The training involved a presentation on the technology, specifications of the device itself, and instructions on operating the device. The field demonstration component involved generating leaks on equipment as well as leak surveying using the acoustic device at a few Metering and Regulating (M&R) stations. The project team is currently reviewing and analyzing the data collected from this preliminary field testing.

The project team will begin a market and product review of commercially available acoustic leak detection devices. Based on the findings from the market review, the team will begin working on a test plan for laboratory testing and select a device to test.

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SUSTAIN H2 Storage

SUSTAIN H2 is focused on accelerating the deployment of safe and cost-effective large-scale underground hydrogen storage. The program leverages scientific expertise, market insights, and industry collaboration to address technical challenges and provide guidelines for the safe and economical implementation of underground hydrogen storage infrastructure.

Project Description

The primary focus of SUSTAIN H2 is to conduct a comprehensive assessment of large-scale Underground Hydrogen Storage (UHS) development across all U.S. regions, considering technical aspects such as capacity, efficiency, safety, and potential infrastructure reutilization, along with economic feasibility. Additionally, SUSTAIN H2 strives to furnish business developers and regulators with overarching guidelines and information to facilitate the safe and cost-effective deployment of UHS.

Deliverables

The project team will populate regional storage databases and conduct comprehensive geological assessments including mapping, modeling, imaging, and analysis to develop selection criteria for hydrogen storage sites. The team will create operations and safety frameworks and compile supply-demand analysis for regional and national hydrogen markets.
Additionally, the project will conduct techno-economic analyses and market assessments at regional and national scales, evaluate policy and regulatory compliance, and provide unbiased, peer-reviewed technical briefing materials. The team will consolidate field screening and development workflows, synthesize comprehensive field development plans, and propose potential field pilot locations and designs..

Benefits

Operators with natural gas storage facilities can lead energy storage expansion efforts and ensure energy security by using their existing infrastructure to stabilize energy demand fluctuations through long-duration storage. As energy demand continues to grow at an unprecedented rate, there is a need for innovative storage solutions that can accommodate vast quantities of hydrogen, both on small and large scales. These solutions must not only be cost-effective but also geographically versatile, ensuring greater resilience and reliability for energy suppliers, distributors, and consumers alike. Through technological advancements and infrastructure adaptations, SUSTAIN H2 aims to unlock the full potential of hydrogen storage, fostering widespread adoption and fostering growth in the hydrogen market. This, in turn, will drive increased activity across organizations involved in hydrogen production, transportation, storage, and delivery, ushering in a new era of reliable energy utilization.

Technical Concept & Approach

SUSTAIN H2's research is organized along four technical working streams that provide input into the development of the regional case studies and ultimate field implementation plans.

The first workstream focuses on geoengineering. The team will assess underground storage potential in all U.S. regions by conducting and compiling geological assessments, including mapping, modeling, imaging, and geological analysis, to populate regional storage databases. Selection criteria for hydrogen storage sites will be developed by performing screening experiments and evaluating reservoirs through literature review, data compilations, modeling, simulation, and testing, with a focus on risk assessment covering microbiology, geomechanics, and geochemistry.

The second workstream covers technology and operations. The team will engage utilities to explore the seamless integration of storage infrastructure with existing transport infrastructure and develop operations and safety frameworks by assessing well design and construction considerations, monitoring and surveillance requirements, and evaluating performance in terms of well integrity and compatibility with hydrogen.

The third workstream addresses market-driven recommendations. The team will analyze economics, markets, and business concepts, focusing on risk management, mitigation, and value-chain integration, and leveraging existing studies. Supply-demand analysis for regional and national hydrogen markets will be compiled. Storage capacities needed will be estimated and recommendations provided based on existing capacities and geologies. Techno-economic analyses and market assessments at regional and national scales will be conducted, leveraging existing studies.

The fourth workstream covers safety and compliance considerations. Policy and regulatory compliance will be evaluated, including licensing, permitting, monitoring, oversight, intervention, decommissioning, and aftercare. The project will facilitate providing unbiased, peer-reviewed technical briefing materials designed to raise awareness, share insights, and spark dialogue around underground hydrogen storage. By translating complex technical topics into accessible narratives, the project is helping to build a more informed and engaged stakeholder community — and ensuring that the knowledge being generated doesn't stay siloed. Research findings and field experiences from each workstream will be consolidated into field screening and development workflows. Data and insights will be synthesized into operational considerations for comprehensive field development plans. The team will benchmark promising geological stores for hydrogen and propose potential field pilot locations and operational guidelines.

Results/Status

SUSTAIN H2 was officially publicly launched in September 2024, leading the team to conduct and participate in significant outreach and knowledge sharing events. The SUSTAIN H2 team headed to Houston for the Gastech Conference, co-hosting the GTI Energy Collaboration Showcase Social and hosted a panel session in collaboration with the Texas Hydrogen Alliance and NeuVentus, with experts from GTI Energy, RMI, FCHEA, and the Clean Hydrogen Future Coalition.

The team also conducted a series of successful webinars including LinkedIn Live engaging with the audience and sharing the latest developments, GTI Energy Tech Talk presenting how SUSTAIN H2 is evaluating the feasibility of UHS, GTI Energy Future Focused Webinar discussing the importance of global collaboration to enable large-scale UHS with experts Serge van Gessel and Hadi Hajibeygi from IEA Task-42, and State Geological Surveys Webinar engaging with state geological surveys via a special session to evaluate region-specific geology and storage capacities.

The team published catalyst blogs on the significance of broad collaboration through IEA's UHS task force and summarizing SUSTAIN H2's launch at Gastech. The team also published a LinkedIn article on representing SUSTAIN H2 at hydrogen-related conferences and workshops road tour and sharing more about the need for SUSTAIN H2. SUSTAIN H2 was featured in IEA's Hydrogen TCP-Task 42 biannual newsletter highlighting critical objectives of SUSTAIN H2. Daniel Weeks from S&P Global Market Intelligence published an article on the newly launched SUSTAIN H2 project, showcasing GTI Energy's expertise and emphasizing the potential alternatives to cavern storage.

The team facilitated the session on "Hydrogen Transportation and Storage" at West Virginia University's Long Duration Energy Storage Workshop, featuring representatives from the U.S. DOE, SHASTA, universities, and the hydrogen industry. The team also co-chaired a session at the AGU conference on "Enabling Field-Scale Demonstrations of Underground Hydrogen Storage in Porous Rocks" that explored advancements toward large-scale UHS implementation and economy-wide adoption.

SUSTAIN H_2 successfully forged partnerships with 20 organizations, including industry leaders, prominent academic institutions, national labs, and a cohort of collaborators from state geological surveys, enhancing the footprint of the initiative. The team connected stakeholders, transformed competitors into collaborators, and bridged technical expertise gaps cost-effectively.

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OTD Operations Technology Development

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 assessing suppliers' quality management systems.

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. 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.

The scope of GTI Energy's Quality Audit Program (QAP) is to audit selected suppliers using federal codes, industry standards (API, ASTM, ASME, MSS SP, NACE, CSA, and ISO), customer-specific, manufacturers' internal, and quality management system requirements such as ISO 9001 and API Q1.

Deliverables

The deliverables for the program will be reports for each audit, corrective action responses for findings identified during the audit, and annual summary reports. Only program members are eligible to receive the audit and corrective actions 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 by creating efficiencies and cost savings by consolidating audits into one program, increasing the number of audits performed, creating leverage and increasing influence with suppliers, utilizing certified auditors with extensive experience, providing high-quality audits with consistency and standardization of the audit methodology, and allowing internal resources to focus on the core business rather than auditing.

Technical Concept & Approach

The suppliers included in the program audits are selected by the program members at the beginning of each year based on commonality of use, past performance, and ongoing quality issues.

The audits performed are based on the process approach methodology of the ISO 9001:2015 Quality Management Systems per the requirements and inquiries from sponsors. Since 2015, the criteria/scope of the audits changed to focus more on industry standards and utility requirements.

On average, up to 19 processes are covered at each supplier site, including specific manufacturing and quality management system processes.

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 Sponsor. The audit process is a combination of performance and compliance-based audits (verifying evidence of compliance versus reviewing actual performance).

All data related to this program's activities is maintained in Onspring, a database designed specifically for the program. Customers have access to this application, including audit schedules, audit reports, corrective actions, metrics, and more.

Metrics for both auditors and suppliers are being developed and monitored throughout the program. Examples of metrics include vendor performance scores, audit report turnaround time, number of corrective actions created, time for corrective action closure, number of overdue corrective actions, etc.

"At Southwest Gas, safety and quality are at the heart of our core values. That's why we appreciate the OTD Quality Audit Program and the additional assurances it provides. With OTD, we know that critical gas carrying component manufacturers have controls in place to ensure the quality of the products we purchase. By ensuring that manufacturers' quality programs are robust and controlled, and that products are only purchased from top-notch suppliers, Southwest Gas can continue to provide safe and reliable natural gas service to the communities we serve."

- Cynthia Davis
Operational Quality Assurance Manager
Southwest Gas Co.

Results/Status

A new ranking system was created to quantitatively assess suppliers' quality systems and to show the strengths and weaknesses of the organization. These scores can be used as a reference in determining whether the company is making improvements going forward.

In 2024, the team completed 14 quality audits as planned. The team also published reports and reviewed the results of audits performed with customers when appropriate.

The project team planned and executed the annual Supplier Quality Audit Workshop hosted by Southwest Gas on November 2024 in Las Vegas, NV. During the workshop, the project team presented the results of completed 2024 audits and discussed the names of potential sites for the 2025 audit cycle and improvements to the program.

The team will finalize the list of suppliers for the 2025 audit cycle, start contacting vendors, and schedule audits. Implement updates in Onspring and conduct Onspring re-training if needed. The team will continue working with vendors to close their pending corrective actions from the audits completed in 2024.

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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.

OTD
Operations
Technology
Development

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 and UL committee 2034 that has jurisdiction of UL Standard 1498 on fuel gas detectors.

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, the first edition of which was published in 2022.

Benefits

The results of this research allow utility companies to add to their environmental and safety public-awareness programs by offering technically validated information regarding the reliability and enhanced safety that in-home methane detectors can provide.

Technical Concept & Approach

Specific tasks in this project 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.

In 2024 work on the second revision for NFPA 715 began. The second edition was published in 2025.

UL TC 1498 (gas detection equipment) met with other TC groups (TC 9200 - toxic gas detection, TC 2075 – gas and vapor detectors and sensors, and TC 2034 - carbon monoxide alarms and gas detectors) to discuss comments received in a recently proposed Guidance Document for Gas Detection Equipment. The document is intended to provide guidance for manufacturers, agencies, regulators and users on the selection and applicable usage of gas detection equipment. Additional work was assigned to TC 9200 to draft a new Action Category of Warning Section to the guidance document.

UL TC met in January 2025 to discuss the potential to convert UL 1484 into a binational UL/ULC Standard by harmonizing the U.S. standard with the Canadian standard. The consensus was to move forward.

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OTD Operations Technology Development

Remote Gas Sensing for First Responders Phase 4: Commercialization Support

The objective of this project is to develop pre-commercial ready units that can be tested by sponsors at actual leak sites.

Project Description

The goal of this project is to work on the commercialization process to develop field ready units for testing and deployment. The team expects to have a commercial product ready for distribution within 24 months following this project. It will be important to collect the user requirements from sponsors so that the final product meets customer expectations. Specifically, there is consideration to combine the technologies (first responder device and the unattended methane monitor) into one single commercial product.

Deliverables

Deliverables for this project will include the design criteria and product specifications, field ready units, a summary of evaluations and final report.

Benefits

The safety of workers, first responders, and the public will be greatly increased by being able to monitor gas concentrations in the atmosphere of buildings and other structures remotely. The remote device wirelessly provides real-time information back to first responders, gas company personnel and others in charge of monitoring and assessing the gas levels in the structures.

Technical Concept & Approach

Specific tasks in this project include:

Development of Field Ready Units

The project team will be working with Sensit, and user requirements will need to be defined. Examples are: Intrinsically safe; Battery life (rechargeable?); Wireless communication method; Security for devices; Use case; Size; Combination of first responders and unattended methane monitor into 1 device; Data management. These items will be documented as guidance and reported to the sponsors. Once the design criteria and product requirements have been established and approved, Sensit will develop field ready units with a focus on hardening the devices to withstand rigors of various field applications. Applications could include residential leak investigations, monitoring of leak repairs and job construction sites. Approximately 12 devices will be developed and distributed to sponsors for testing and evaluation at leak sites.

Product Evaluations at Leak Sites

The team will travel to one or more facilities designated by the sponsors to present and demonstrate the devices. The ideal location for the demonstrations would be a leak training facility where known leaks are available. If possible, demonstrations will be located such that multiple utilities can attend. This will allow capture of direct feedback on the operation and features of the system. It will also allow the utility personnel to receive basic training in the use of the devices. Operators will also have an opportunity to retain the prototypes and perform independent testing.

Results/Status

The team demonstrated a prototype tool for active leak investigation. However, after reviewing the Voice of the Customer (VOC) the OTD sponsor utilities have expressed interest in seeing a prototype of an unattended methane monitor (UMM). The purpose of the UMM was to be a leave-behind device to monitor conditions on a site before or after a repair has been made. It was intended for longer-term deployment, not an active investigation with personnel on site.

The team will discuss a path to develop a UMM prototype and possible changes on the project scope will be determined.

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OTD Operations Technology Development

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 are 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.

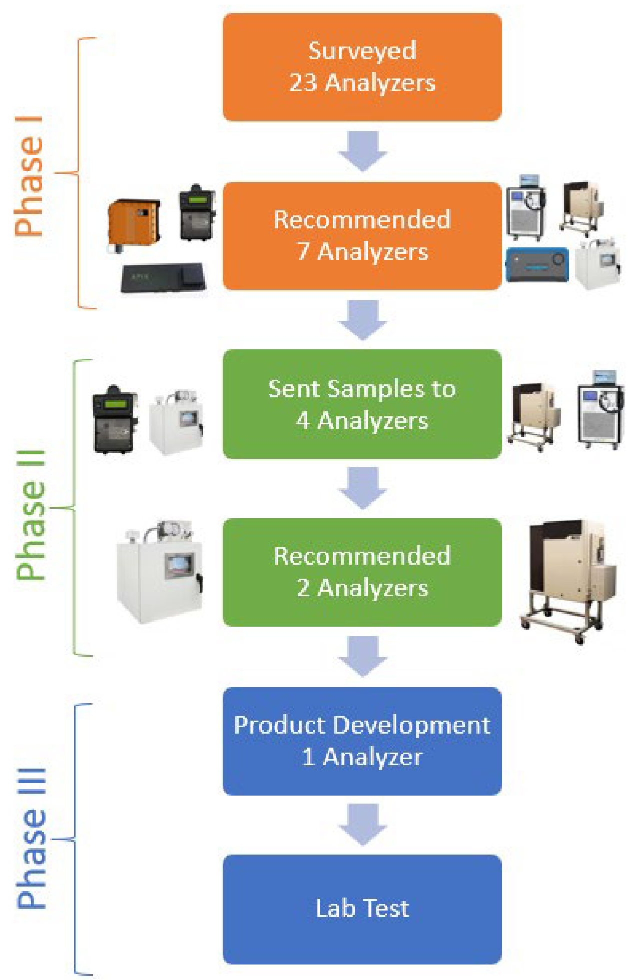
Manufacturer claims are being addressed through the preparation of artificial standards mimicking natural gas and natural gas with low, medium, and high concentrations of trace biomethane constituents. From the resulting chromatograms, the technologies will be evaluated for sensitivity, selectivity, and repeatability.

Deliverables

The deliverable will be the development of the first market-ready analyzer to monitor the predominant species of BTEX, siloxanes, organic arsenics, halogenated hydrocarbons, and n-nitroso-di-n-propylamine. This also includes the evaluation of the on-line analyzer in the form of quarterly reports and a final report. The online analyses will be compared to laboratory measurements following standard methods to evaluate precision and accuracy. Operational experience will also be evaluated.

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. Online 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

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 clean-up 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. Results showed two potential candidates warranting further investigation into product development.

Status

Phase 3 of the project began in 2023 and intended to develop and test the online analyzer validated as best performing in Phase 2 for monitoring the unconventional trace contaminants. Delays with executing the subcontract have prevented the project from moving forward. A meeting was held between the technology provider and project sponsors was held in December 2024, to discuss instrument capabilities and industry interest in the potential modifications. A meeting with project sponsors will be scheduled in Q1 2025 to discuss the revised scope or to cancel the project.

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OTD Operations Technology Development

Soap Solution Comparison Study for Rate Estimation/ Hazard Assessment

The objective of this project was to perform a comparison study between soap solutions to understand if solution additives may lead to relatively large variations in bubble sizes or formation rate with the goal of quantifying discovered leaks.

Project Description

The objective of this project was to evaluate whether soap solutions of varied formulas respond uniquely in a soap test under various pressures, temperatures, and flow rates. The evaluation focused on observing whether variations in bubble size, frequency of bubbles, and formation patterns are indicative of a potentially hazardous event or result from variables such as pressure, wind, and other factors.

Previous work was done in OTD Project 7.17.d (Phase 1&2): Methodology to Estimate Flow Rate of Above Ground Leaks Using a Soap Test. In these previous projects, soap solution was presumed to have an impact on bubble formation based on the proprietary additives. It was found that one of the soap solutions produced bubbles that were significantly larger than two other soap solutions at larger flow rates (5 scfh).

Deliverables

Deliverables include a comparison study that examines soap solution that may demonstrate variation in bubble size due to additives and/or preparation and a report that summarized the findings of the lab tests and any conclusions that can be determined in the results.

Testing setup for the first set of tests. Compressed air was connected to a pressure gauge and a flow meter, and a vise was used to hold the pipe piece in place. Bubbles formed at an end cap where air ultimately escaped.

Benefits

Utility companies often use soap to assess if an above ground leak should be categorized as hazardous or non-hazardous. Understanding how bubble size and formation rate might vary across soap solution products allows companies to assign the type of emergency response and/or mitigation needed to a given leak.

Technical Concept & Approach

Specific tasks in this project included:

Laboratory Testing

All testing was conducted in laboratory to limit external variables. Work prioritized largest bubble size at controlled flow rate as well as observation of transitional phases in bubble formation (foam to foam/bubbles to bubbles only). Temperature effects were also observed in controlled environment chambers.

Soap solutions used for testing

Two examples of laboratory testing and photos obtained. The left photo is a soap solution tested at 0.25 psi with a flow rate of 0.05 scfh. The right photo is a soap solution tested at 30 psi with a flow rate of 5 scfh.

Analysis

Focus was on variation in largest bubble size at ~5 scfh, variation in transitional flow rates, and temperature effects.

Results/Status

The project team evaluated the soap bubble method to estimate emissions on aboveground assets in three project phases. The first phase demonstrated a trend between increasing flow rate and soap bubble appearance. The second phase documented the effect of pressure on the resulting flow rate and included a preliminary review of the error expected in human observation of the soap appearance. This project has reviewed the potential effects of soap solution additives on the estimation bins developed in Phase 1.

The team conducted various tests during this project and several conclusions were formed based on the effects of pressure, flow rate, temperature, and soap solution. It should be noted, however, that there were only 3-5 replicates for each set of conditions which may not be a sufficient sample size to be confident in these conclusions.

For the test of varying pressures, very little difference was found in bubble size across pressure for all soap solutions and very little difference between soap solutions for all pressures. However, there were differences in bubble size across pressures for one soap solution and across soap solutions for 60 psi.

For the test of varying flow rates, the effect of flow rate provides a significant difference in bubble size, but it is not dependent on solution, and there was no evidence found of a significant difference in bubble size between soap solutions.

Overall, the soap method can be useful for identifying and potentially classifying leaks, however it is likely not a good way of quantifying them. Future testing should consider high volume testing across flow ranges and pressures to better estimate the variance between bin ranges. A computer-generated imaging program may be able to analyze the average bubble size and rate of formation, providing potential additional factors that could reduce the variance in estimation.

The final report of Soap Solution Comparison Study for Rate Estimation/Hazard Assessment was completed and released to OTD members in August 2024.

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OTD Operations Technology Development

Best Practice for Venting a Building

The objective of this project was examine procedures that are currently in use by both utilities and emergency responders as well as identify additional means of evacuating gas from buildings and develop best practice based on the findings.

Project Description

This project examined existing practices for safely venting natural gas from buildings during leak emergencies, identified gaps in current utility procedures, and provided recommended best practices. The investigation included analyzing both utility and emergency responder protocols, as well as evaluating enhanced ventilation methods such as industrial fans to increase airflow through leak sites beyond traditional approaches like opening windows.

Deliverables

Deliverables for this project included a review of fire codes and existing utility procedures, a summary of best practices for responding to gas-filled structures and evacuating the gas, and an exploration of mechanical options for gas evacuation from buildings. Recommendations were detailed in the final report.

Benefits

It is imperative that companies utilize the most effective procedures to ensure that a structure has been completely evacuated of leaking natural gas and maintain safety. Effective procedures help to mitigate risks associated with lingering leaks or elevating concentrations of methane within a building or confined space while also ensuring re-entry into the building is safe.

Technical Concept & Approach

Specific tasks in this project included:

Investigation of Current Best Practices and Alternative Methods for Evacuating Gas from Buildings

Project sponsors were surveyed for their current methods of dealing with accumulated gas leaks inside of structures. Fire codes were also surveyed to note how emergency responders are expected to react in certain gas leak scenarios.

Recommendations may include using mechanical means for ventilation or the use of devices that allow for continuous remote monitoring of methane concentrations to ensure individuals are returning to a safe environment.

Results/Status

The team categorized the best practices developed as part of this project into four areas:

Standard Operating Procedures

Having an SOP that addresses ventilation techniques for natural gas from structures is a common practice within the industry. It is also a common practice that utility operators and fire department agencies work together when developing and reviewing their SOP's for ventilating natural gas from structures. This effort will help improve communication between both organizations when responding to emergencies together.

Ventilation Methods

Positive pressure ventilation (PPV) fans can be beneficial when ventilating small and large spaces with

Firefighting mobile unit

high concentrations of natural gas or dead spaces (i.e., attics and crawl spaces) with gas accumulations. The fan creates positive pressure within the structure or space being vented so that the natural gas can be forced outside the structure.

Sequential ventilation may be more beneficial for multi-story buildings. By controlling the exhaust openings that are open at any one time and proceeding in sequence, one blower at the ventilation point may be able to supply enough pressurization to ventilate a sizable building. Sequential ventilation can be also applied when venting apartments.

Equipment

An important consideration when using any powered equipment in a potentially dangerous environment is intrinsic safety. Fans and blowers should be intrinsically safe to avoid introducing an ignition source into an environment with a concentration of flammable gas. To ensure that this is the case, is encouraged that the utility company and fire department agency used the same type of gas monitoring equipment and the same type of PPV fans. In some cases, this equipment was provided to the fire department agency by the local utility company.

Training

Generally, first responder training is performed annually. Details of what to consider in designing annual training programs can be found in the final report. Additionally, it is encouraged that utility operators try to perform joint training with fire department agencies on the ventilation of natural gas from structures.

The final report of Best Practices for Venting a Building was completed and released to OTD members in August 2024.

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OTD Operations Technology Development

Center for Gas Quality (Gas Quality Database Phase 3)

The objective of this project is to provide continuing maintenance and updates to the trace constituent gas quality database created in Phase 1 and further developed in Phase 2.

Project Description

Our industry has evolved significantly in the types of gases commonly extracted, transported, and used. The proliferation of shale gas development and other supply opportunities in the mid-2000s shifted the focus to LNG export opportunities, a significant swing in supply dynamics over a very short period of time. Now Renewable Natural Gas (RNG) production is a significant greenhouse gas mitigation opportunity as we find new technologies to process and use this valuable resource. This trend is expected to continue into the foreseeable future as more RNG supply sources are brought to market. Hydrogen blending will further add to the gas supply revolution. The ongoing supply "revolution" in North America demonstrates the need for a consolidated approach for housing key technical information necessary for efficient and effective "good science and common sense" based decision making when dealing with alternative, pipeline quality gas supplies.

Deliverables

Deliverables for this project include the updated trace constituent gas quality database, including data from literature, available lab analyses, and shared data from OTD and PRCI members, an additional module which will be added based on feedback from sponsors, and a final report.

Benefits

This project created a database to facilitate the industry's understanding of Renewable Natural Gas (RNG) trace constituents and provide background knowledge to successfully integrate RNG into their system to meet their decarbonization goals without compromising their assets. This database ensures renewables can be integrated and do not impact system operations or safety.

Technical Concept & Approach

Specific tasks in this project include:

Database Refresh and Maintenance

New data and other resources will be curated and combined with the existing data and added on a quarterly basis. New concentration data will be blinded as to its exact origin, but will be identified by generic region, feedstock, and completeness of upgrade from the raw biogas. This is an identical process to Phases 1 and 2. Possible co-funding from PRCI would add additional sponsor data and expand the dataset to include international sources and also incorporate site maintenance and will support activities needed to add new users. In addition, a new module will be built based on feedback.

Results

The team has been collecting user responses to surveys for new data submission, operational issues, and new user addition to the site. Data will then need to be added to the site. Improvements were made to the site aesthetics, report formats and Power BI functionality. All these efforts should improve user experience. A module was created to request additional users be given access to the site. This will better control access and ensure new users are added in a timely fashion.

Status

The project was presented at tcBiomass 2024 and will be presented to PRCI at the REX conference in March 2025 to continue the database socialization effort. A proposal was prepared for PRCI to secure additional co-funding.

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OTD Operations Technology Development

Characterizing Methane Emissions from Purging Activities

Researchers developed a method to quantify the volume of natural gas emitted during the commissioning of a pipeline. This method was 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 involved an investigation into methodologies needed to quantify emissions from gas purging with the intention of ultimately providing solutions to lower overall methane emissions.

Deliverables

Deliverables for this project included a method to quantify volumetric quantities of methane emissions produced from a pipeline purge and a final report.

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

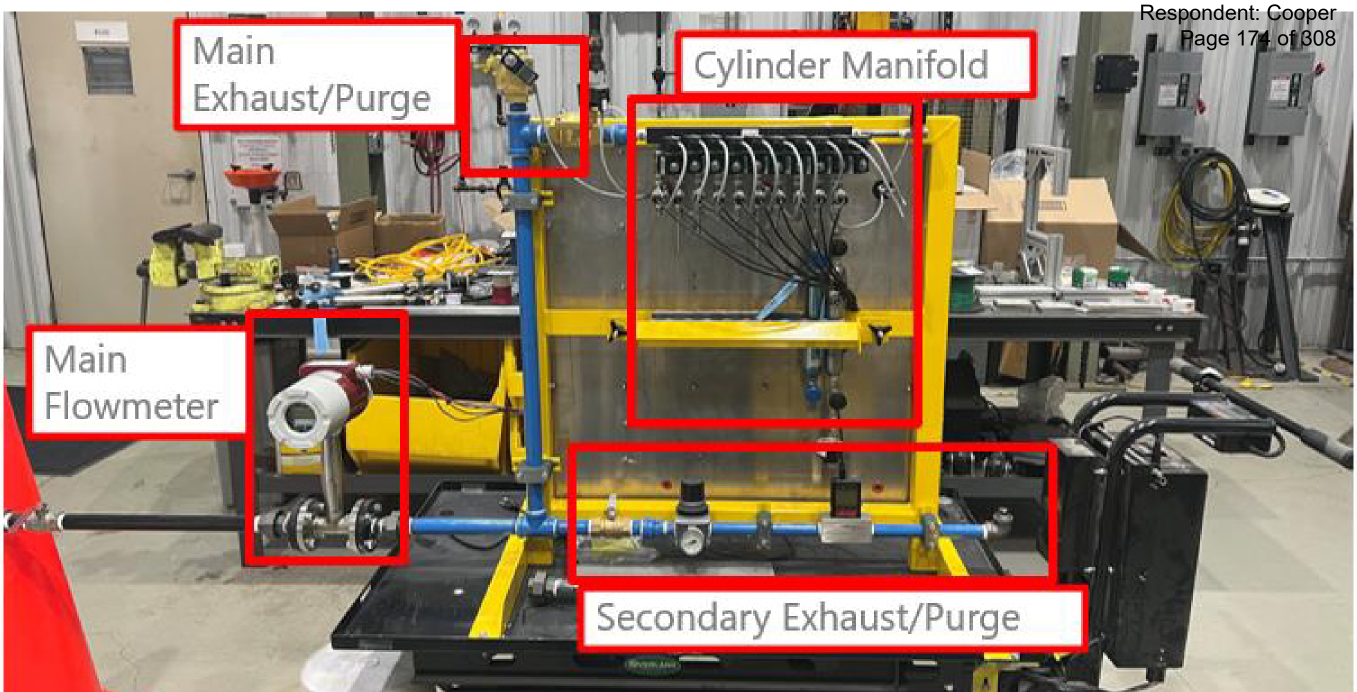
The project team reviewed commercially available technologies and developed a feasible approach to measure volumetric quantities of natural gas emitted during a purge. The team then validated the proposed methodology via testing. If successful, a Phase 2 project would focus on executing project sponsor field trials of the methodology.

Results/Status

The original design involved a thermal mass flow meter and a secondary purge point with a pressure regulator to reduce the flow speed to the gas analyzer or Combustible Gas Instruments (CGI) to measure the concentration. This design, while simple, did not consider the potential error in measuring oxygen or methane with a standard CGI device.

To better understand this potential error the project team suggested an alternative approach for benchmarking the volume of natural gas emitted during purging procedures. To this end, the project team altered the experimental design by adding sample cylinders filled at timed intervals during purging. The project team designed and constructed a modified purging endpoint automated to collect timed samples to be analyzed by Gas Chromatography (GC). A secondary purge point was added with a pressure regulator to reduce oversaturation and error when using a handheld Combustible Gas Instruments (CGI) device for methane measurement. An in-line mixer was installed to observe potential efficiency gains from allowing air and natural gas to mix just before releasing to the atmosphere.

Both nitrogen and natural gas were used as a purging gas, forcing air from 800-foot plastic pipeline over 30 minutes purging trials. The oxygen was reduced to less than 1% in the nitrogen trials within 90 seconds. This was not suitable for understanding the CGI's potential error. In trials with natural gas, the oxygen was again reduced quickly, but methane content stayed near 91% gas-by-volume when measured with a CGI. If this holds true, the field-deployable system could utilize the same components, given the CGI has an appropriate oxygen sensor.



Completed Test Rig with Cylinder Manifold and Secondary Purge Point.

The project team obtained from this project the following conclusions:

• Testing with varying volumes will help develop a better profile of emissions. The piping section used in this project limited the ability to build a larger data set.

• A static mixer upstream of a purge vent may offer efficiency gains, i.e., reduced time, in purging procedures. This may be suitable for further investigation with larger volumes.

• Measuring the oxygen component of air may better indicate when a purge has been completed when the pipe contents are air. This is not a suitable solution when another inert gas such as nitrogen is used prior to natural gas injection. CGIs are often calibrated for methane, the major component of natural gas. Therefore, natural gas quality and methane concentration can vary based on origin, meaning CGI readings may also vary. Air will have a more consistent composition.

Extended testing is needed to confirm the conclusions from these trials, but there are some positive indications from using an in-line mixer. An oxygen sensor may be better suited to confirming that air has been removed from the pipeline. These practices may reduce the emissions currently released during these operational activities.

This project is complete. The final report on Characterizing Methane Emissions from Purging Activities was completed and released to OTD members in October 2024.

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OTD Operations Technology Development

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.

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

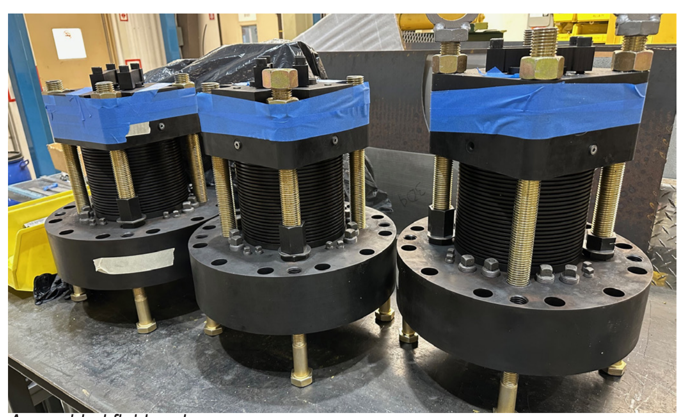
The project team will submit quarterly progress reports to sponsors. A complete prototype will also be built and tested. Data and results from this testing will be summarized and provided to members.

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.


Assembled fluid ends

Key components (e.g., valves, seals, and motors) will be designed and integrated into the compressor solid models and undergo extensive thermal and structural finite element analysis.

A test apparatus will be used to validate and improve the linear motor compressor performance and sub-assembly performance. Results from this testing will be used to improve the assumptions in the simulation.

The project team will verify operation in a relevant environment that matches real-world conditions for the leak recovery compressor, including verifying that the controls and safety features are working properly.

Results

In 2021, investigators at the University of Texas at Austin created a simulation of the compressor stages and explored variations in many physical parameters to down-select the preferred motor and compressor design characteristics and to verify that they meet the performance requirements across a broad range of simulated operating conditions. After evaluating many variations in design and operating parameters, appropriate design parameters were chosen for piston areas, stroke lengths, and check valve sizes that produce the right outlet pressures and flows using assumed inlet pressures and stroke frequencies.

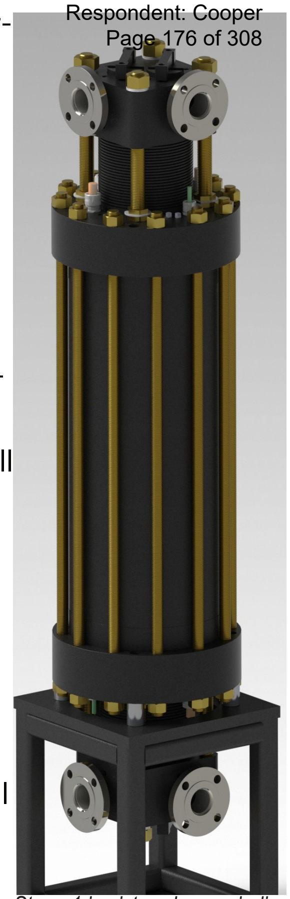
Simulations were conducted to predict dynamic pressures and temperatures in each stage of compression. These simulations demonstrated that the compressor should be able to deliver 50-60 standard cubic feet per minute of flow from an atmospheric inlet pressure to a 1,500-psi discharge necessary for capturing leaked methane and returning it to a midstream pipeline.

This simulation tool was also used to evaluate whether a three-stage compressor could be used instead of a four-stage system. Results showed that the project goals could be met with a three-stage compressor, so that is the configuration that was 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 was modified for the three-stage compressor design. The team also identified suitable coalescing filters and 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.

The compressor design has been completed and detailed drawings have been finished. The seal design was changed to address issues with the seal speed and wear. The motor assembly was changed to drive each stage of compression with a separate motor.



Stage 1 is pictured on an individual stand that will provide easy access to the bottom piston

The team has completed a detailed economic and business case model. The analysis was done considering a stand-alone business operation. Several product scenarios were considered.

Status

The compressor, power electronics, and test loop are undergoing final assembly at GTI. Following assembly, the compressor will be commissioned to verify that all data collection and safety systems are working as intended. The compressor will then be operated on nitrogen before switching over to natural gas. The testing will verify that the unit can accurately match the real time leak rates that might be seen in the field, and that the gas can be efficiently returned to the pipeline.

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Advanced Tools for Methane Emission Rate Estimation

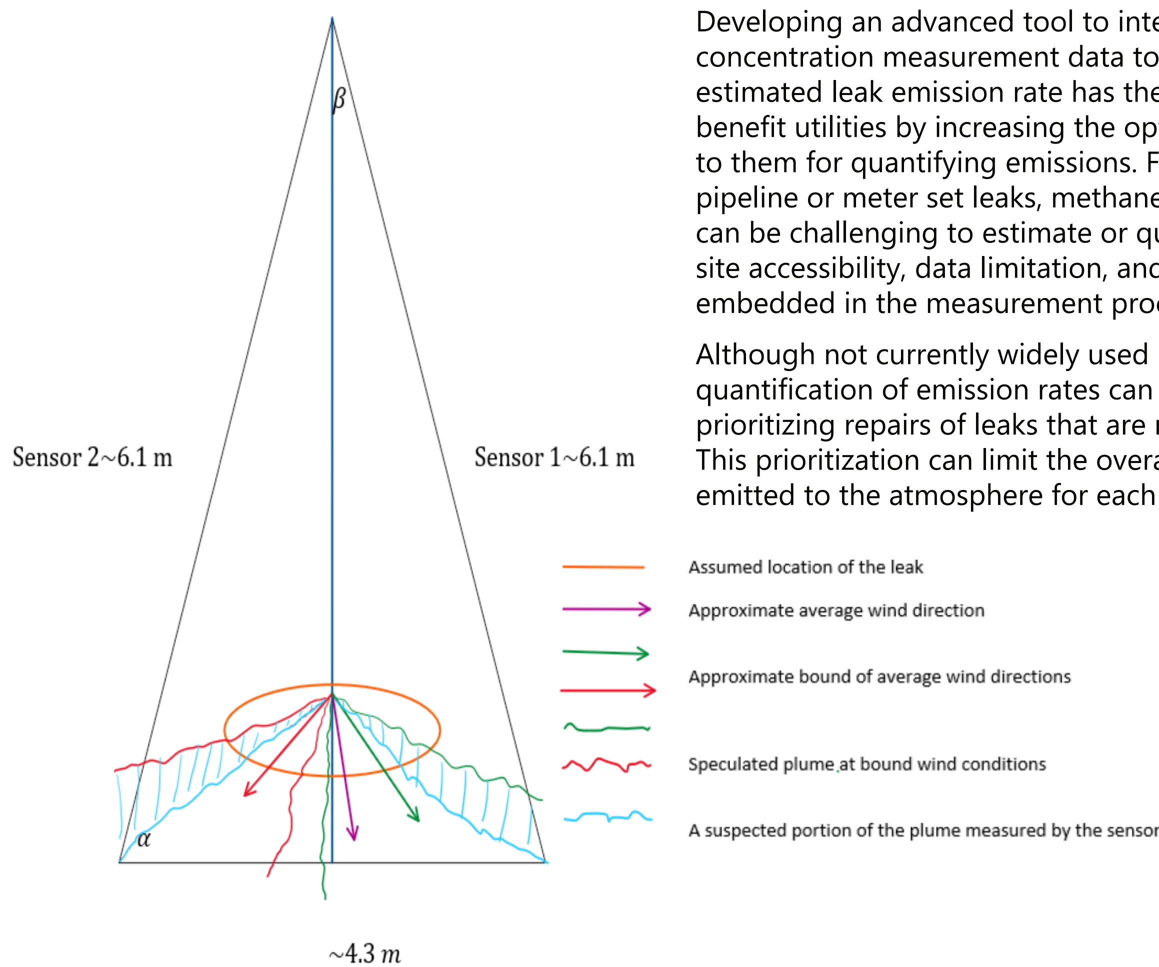
The objective of this project was to develop an advanced tool to estimate the emission rate by incorporating spatial methane concentration measurements. If successful, a follow-on project will be proposed to perform field testing and evaluation.

Project Description

Currently, concentration only measurements are collected in the proximity of gas leaks using handheld devices such as combustible gas indicators or infrared-based sensors. Leak grading relies on concentration measured near the leak at a particular point in time.

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 software/modeling tool to estimate the emission rate by incorporating temporal and spatial methane concentration measurements. A comprehensive proof-of-concept study will be conducted to demonstrate the feasibility of this methodology, placing emphasis 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

Deliverables for this project included an advanced analytical tool that can provide more accurate estimation of methane emission rate and a final report.

Benefits

Developing an advanced tool to interpret field concentration measurement data to produce an estimated leak emission rate has the potential to 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 accessibility, 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 hazardous. 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 toolbox.

Technical Concept & Approach

Specific tasks included:

Technology and Machine-Learning Algorithm Review

In this task, an in-depth literature review was conducted to gather information on multiple aspects of the methane emission measurement process. The focus was placed on obtaining existing utility datasets that report in-field concentrations and leak emission rates (something that is not usually readily available). The technology review made sure the developed algorithm was equipped with the capability/interface to incorporate the state-of-the-art measurements. Additionally, the team reviewed the most recent advancement in machine learning, especially deep-learning methodologies which served as the theoretical underpinning of the developed model.

Explainable Artificial Intelligence (XAI) Algorithm Development

Researchers designed and developed a flexible explainable machine-learning model that incorporates air-dispersion models, field-concentration measurements, and machine-learning algorithms.

Model Demonstration

The project team demonstrated the process of estimating methane emission rate using the developed software tool. An earlier project provided data from an open-path, laser-based methane detector in a long-term, outdoor deployment. This data included several calibration points wherein a known volume of methane was released at a given time. This task also provided the template for integrating the developed tool with a leak survey device for field evaluation in a follow-on project.

Results/Status

This project provides a proof of concept for implementing an advanced modeling and parameter estimation methodology for locating and quantifying above-ground methane leaks. The approach uses an optimization problem to estimate the model parameters which maximize the likelihood (probability) of observing the gathered field measurements. This approach provides a histogram for each parameter rather than a single value. The analysis of the results provides insights into the confidence of the estimated values and potential improvements in data collection and modeling.

The specific data from a controlled release experiment was used to test the methodology. Analysis of this specific data set provided justification to use data from one of the two sensors over the other based on the lower mode of the estimated error and higher estimated variability of the horizontal and vertical components of the wind velocity (as indicators of the expected turbulent conditions).

The implementation results suggest that the horizontal leak location could be estimated within 2.5 m to 6 m of the dual open-path laser sensors, which is equivalent to a parallel strip of 3.5 m width, and the leak rate could be estimated with a confidence level of 10% to 40%.

This methodology can provide operators with an analytical tool to prioritize leak repair and quantify fugitive emissions by estimating a leak's location and flow rate while assessing the uncertainty associated with the available data and the model's inaccuracy. It can be adapted to any sensing technology that provides standard methane concentration measurements and atmospheric conditions.

Further testing with existing data would provide additional evidence of the benefits this proof of concept can bring. Additional data (3D wind velocity components) and adaptation to other types of sensors can be added to the potential future work.

This project is complete. The final report on Advanced Tools for Methane Emission Rate Estimation was completed and released to OTD members in September 2024.

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OTD Operations Technology Development

Impact of Trace Constituents on Odor Masking

The objective of this project was to identify potential odorant masking agents that may carry over from incomplete processing at a natural gas processing plant.

Project Description

This project examined the question of which substances possibly present in unprocessed natural gas have the potential to mask odorant based on their chemical properties. This was the first of three proposed phases, with subsequent work to explore whether these substances would indeed mask odorant and possible mitigative measures, and finally to look for online analyzers that could potentially measure masking agents.

Deliverables

This project used a suite of gas chromatography instruments for a variety of analyses on the subject compounds. A total of 125 samples were analyzed from the utility experiencing this issue, including some for baseline. The final report contains results of these analyses, as well as results of olfactory screening (sniff test).

Benefits

Maintaining adequate levels of odorant is essential for safety, and understanding odor masking due to substances potentially present in natural gas enables utilities to be proactive in addressing this issue.

Technical Concept & Approach

Specific tasks in this project included:

Literature Survey of Odor Masking Phenomenon

Focused on a thorough investigation of the literature of odor masking looking at it from the perspective of the natural gas industry and the implications for TBM and THT odorants.

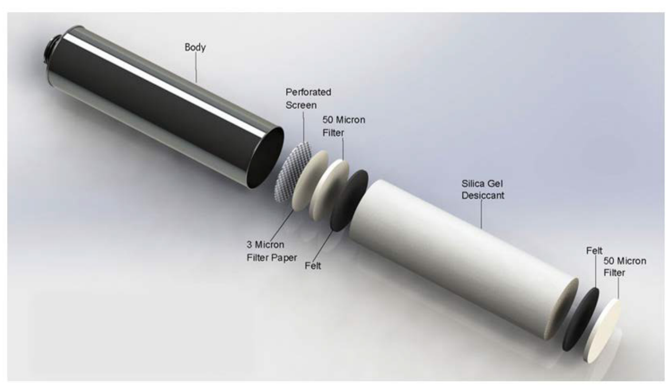
Laboratory Testing of Selected Gas Samples

Gas samples with known odor masking issues were subjected to comprehensive analyses focusing on heavy hydrocarbons and other chemicals known to be present in unprocessed natural gas. The discussions with the pipeline operators and gas processors informed the selection of constituents or constituent classes to analyze. Certain substances potentially present in biogas (such as limonene from citrus in food waste) were also analyzed.

Results/Status

The project team, through analysis of samples, found that the loss of odor perception was most pronounced when the presence of atypical (C11+) heavy hydrocarbons was detected. Adamantanes (not ordinarily seen), associated with the heavy hydrocarbons were also discovered. Analysis of associated silica gel filters also found that the presence of adamantanes tracks with the C11+ content found.

Diamondoids such as adamantane and its alkyl compound derivatives are cage-like, ultra stable, saturated hydrocarbons originating from underground fossil fuel reservoirs. Usually, adamantanes are ignored due to the low concentrations in petroleum, but at larger concentrations the compounds may nucleate and precipitate out due to changes in



Silica Gel Gas Filter Dryer

Sniff Test Experimental Setup

pressure or temperature during production.

These compounds are known to be present in the unprocessed gas/liquid mixture extracted from the wellhead. Although adamantanes will preferentially partition into the liquid phase there remains a fraction of these species which can potentially partition into the gas phase. If the gas is not sufficiently processed before pipeline injection adamantanes could remain in the gas stream.

It is not clear if the adamantanes or the heavy hydrocarbons contributed to the loss of odor perception. Since adamantane has a strong camphor like odor which could mask the sulfur odor of natural gas at sufficiently high concentrations, but the limited sniff testing conducted did not confirm.

Data from both the gas analysis and the filter analysis demonstrate that using an analysis that can measure extended hydrocarbons to track the potential of odor masking is feasible for applications downstream of a natural gas processing plant.

While not the specific focus of this project, another class of compounds suspected to contribute to odor masking are terpenes such as limonene and pinene found in biogas derived from food waste. While the limited sniff testing performed did not confirm the adamantane masking, it did confirm the interference of limonene with detection of the tetrahydrothiophene (THT) odor.

Further odor masking testing is recommended for a selected set of potential odor masking chemicals. This Phase 2 testing should be performed by a subcontractor with odor testing experience who can design such a test safely within the constraints of the concentrations found. A potential Phase 3 could look for or advise in the development of potential online analyzers to measure specific masking agents.

The final report of Impact of Trace Constituents on Odor Masking was completed and released to OTD members in August 2024.

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OTD Operations Technology Development

Accuracy of Hydrogen Analyzers and Survey Instruments

This project involved a laboratory evaluation on the precision, accuracy, and impact of analytical equipment for natural gas blended with hydrogen at concentrations between 5% and 20%.

Project Description

An accurate and precise analytical network that can accommodate the gas composition change from introducing hydrogen builds confidence with operators. 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 conducted 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 were evaluated.

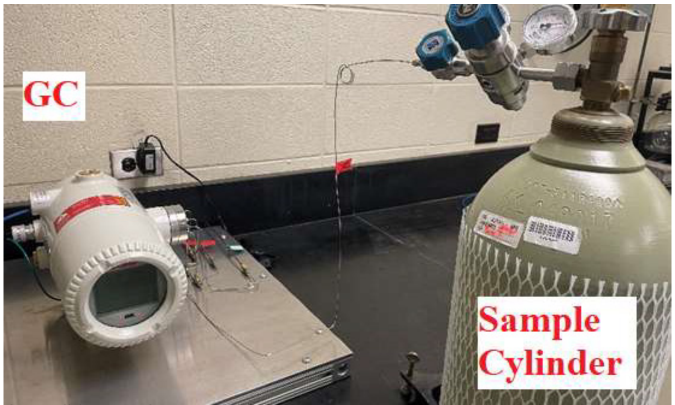
Deliverables

A final report summarizes the results of the two evaluation tasks including determinations of TRL for analytical equipment in regard to natural gas/hydrogen blends.

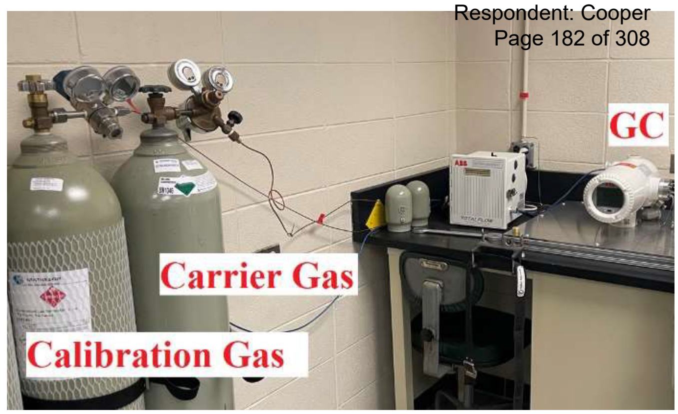
Benefits

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 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

A variety of instruments are being evaluated.



Setup #1 to the Sample Cylinder



be leveraged for this monitoring will help operators safely integrate hydrogen within their networks.

Technical Concept & Approach

A survey was conducted to determine brands and models of online BTU GCs and leak survey instruments used by project sponsors. Based on survey responses, an online BTU GC with an available hydrogen analysis option and four common leak survey instruments representing an array of detector technologies were selected for evaluation.

Testing protocols were set up to assess the instruments' accuracy, precision, and bias for determining hydrogen concentration in natural gas at a range of 5%-20%. The design of this protocol was 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

Four leak detection and survey instruments representing a mix of sensor technologies were selected for evaluation. A testing protocol was developed to evaluate the technical specifications of the selected instruments in the presence of natural gas/hydrogen mixtures at hydrogen concentrations ranging from 0% to 20% hydrogen, and Lower Explosive Limits (LELs) ranging from ~5% LEL to ~40% LEL. Test results show that, as expected, the sensors capable of detecting hydrogen showed the best overall accuracy and precision for the concentration range of hydrogen tested. However, all instruments tested did show a high positive bias for methane. At no test conditions did the negative bias introduced by hydrogen fully negate the positive bias for methane for any of the instruments. As a result, there were no indications suggesting that the probability of a false negative reading would increase when surveying leaks of natural gas mixed with hydrogen at concentrations up to 20% for the instruments included in the test. Precision and bias information for each of the surveyed instruments is available in the final report.

This project is complete. The final report on Accuracy of Hydrogen Analyzers and Survey Instruments was completed in July 2024 and released to OTD members in August 2024.

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PSI Laser QGI Field Testing

Researchers will evaluate advanced prototypes 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 phase evaluated the latest prototype of the Remote Methane Leak Detector-Quantitative Gas Imager (RMLD-QGI) developed by Physical Sciences Inc. (PSI). The goal was 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.

Deliverables

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

Images of the latest iteration of the RMLD-QGI. This advanced prototype is a completely handheld and battery-powered unit based on the RMLD-CSTM footprint.

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 repair. This allows the operating companies to focus their repairs on larger leaks. There is also potential for QGI to reduce costs and training time due to its relative ease of operation.

Technical Concept & Approach

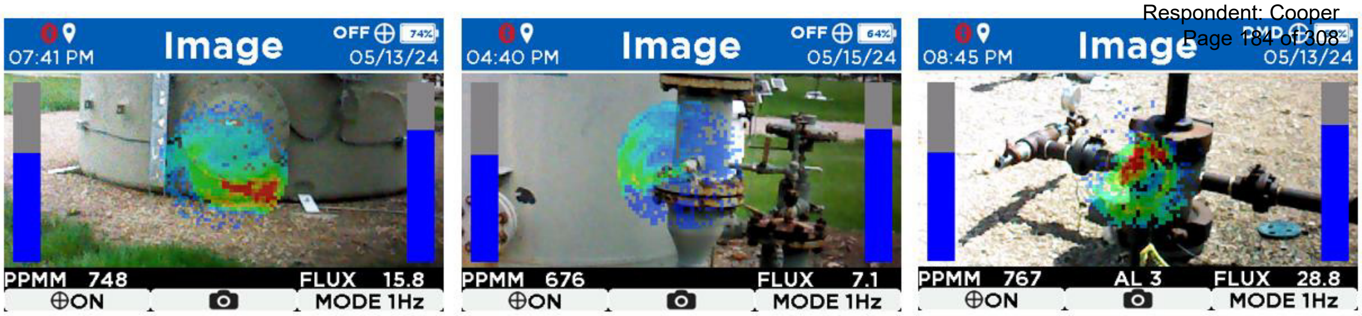
The primary tasks for this project included:

QGI Instrument Readiness

The team prepared the advanced prototype(s) for field testing. Preparations included system calibration, and bench testing. System calibration included laser operating parameters setup, system parameters setup, optical alignments, and two-point measurement calibrations. Bench testing included 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

The team developed 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 perfor-



mance was documented. End-users were trained in operating the QGI, and feedback was collected to improve the QGI product.

Results/Status

The current prototype of the Quantitative Gas Imager (QGI) has demonstrated the abilities to detect methane leaks, visualize gas plumes, and quantify leak rates from a standoff distance. The QGI device proved to be easily operated in the field, new users were confident operating the device after a short training session. The QGI also quantifies leaks with higher accuracy when a full background is present behind the equipment being surveyed (i.e. the full laser beam is reflected back to the instrument). Partial background scenarios can still provide visualization of the leak plume, but the leak rate may be underestimated. There are cases where a very small leak (<1 scfh) can be detected and visualized by QGI. However, leak rate quantification was limited due to the size of the gas plume.

The Methane Emission Technology Evaluation Center (METEC) results with equipment having a full background showed the QGI measurements averaged within +/- 44% of the prescribed leak rates. This larger error is likely due to an assumed operating distance from the leak source across all scenarios. Improved accuracy has been demonstrated when the distance to target is measured and factored into the quantification algorithm. QGI leak rate estimates were consistently underestimated for the equipment surveyed with a partial background.

At the municipal site leak towns, the QGI leak rate estimation of localized leaks such as from meter sets and manholes were within +/- 27 and 35% of the direct quantification method using the Hi-Flow device. For more diffuse ground leaks, the differences were larger (75 to 300%). This is largely due to the leak diffusing beyond the field of view of the scanned laser. Advanced algorithm approaches should be made to "stitch" segments of the diffuse leaks together to encompass leaks fully. Additionally, the direct quantification method of the Hi-Flow device uses a tarp to enclose the area and pulls the gases into a continuous analyzer, which may influence flow rates (especially for smaller leaks); Comparing estimated emission rates of intermittent leaks between the QGI and Hi-Flow is difficult as the Hi-Flow device continuously pulls gas samples into its analyzer. However, the QGI device provides a real-time visualization of the gas plume and estimation of the leak rate without modifications to the leak source environment.

The team at PSI is preparing to commercialize the QGI device. Some of these commercialization activities include: Continued field demonstrations with other LDCs to widen the adoption of QGI; Manufacturing prototypes for early adopters for in-depth and extended field tests; Engaging other sectors within the natural gas infrastructure to widen the potential use cases; Working with instrument manufacturer, marketer, and sales to release the product within a year; Adding features and capabilities derived from user feedback collected in this project.

The project team made suggestions for follow-on projects to expand the application areas including quantification of widespread underground leaks from natural gas pipeline infrastructure, especially in municipal applications; integration into an aerial platform (e.g. quadcopter) for wide area coverage such as landfills, sewage processing plants, animal farms, agricultural sites, etc.; and extension to other gases of interest for greater energy system decarbonization goals.

This project is complete. The final report of Physical Sciences Inc. Laser QGI Testing Phase 2 was completed and released to OTD members in October 2024.

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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 molecules have a smaller molecular weight than natural gas. Due to the difference in molecular size, it was of interest to explore whether threaded connections with sealants remain leak-tight when a hydrogen blend is used

The goal of this project is to observe the impacts of hydrogen-blended gas on thread sealants commonly 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 that hydrogen-blended gas has on sealants within delivery infrastructure.

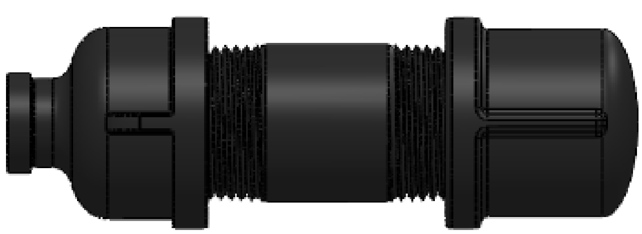
Technical Concept & Approach

The initial plan was to simulate meter set assemblies' working conditions and use threaded assemblies with sealants as a part of the hydrogen flow rig. However, due to delays in the fabrication of the hydrogen rig (OTD 5.21.t), the plan has changed, and the threaded fittings with sealants were evaluated using pre-blended cylinders. Testing was focused on the performance of various thread sealants in a hydrogen blend of 80% of NG and 20% of H2 and natural gas. The project team will analyze results and compare the impacts of blended and non-blended gases on samples.

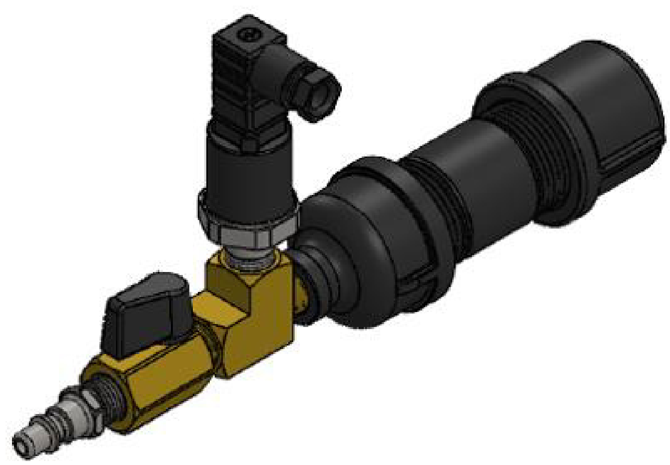
Results/Status

The team received malleable fittings and completed thread inspection to ensure compliance with ASME B1.20.1. All the components to build a testing rig were purchased. The test profile for this project was developed based on the test protocol from CAN/ULC – S642: 2021 Standard for Compounds and Tapes for Threaded Pipe Joints.

60 assemblies, four sets of 15, have been constructed, and completed temperature cycling testing. The first set of 12 samples have undergone an initial



Black Steel 1 NPT Test Sample (1 NPT to ¼ NPT Reducer – 3in Long 1 NPT Pipe Nipple – 1 NPT Cap)



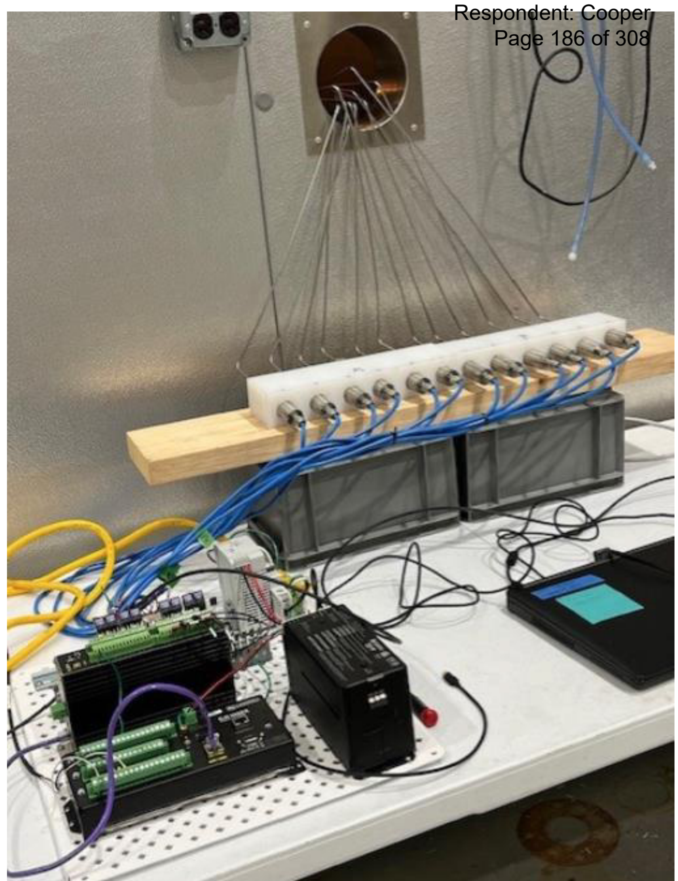
Pressure Transducer Subassembly attached to Black Steel 1 NPT Test Sample


Test samples inside of the temperature chamber

pressure test at 125-psig. Each set of 12 samples was pressurized with natural gas or 80/20 NG/H2 blended gas and placed into a temperature cycle. The pressure of each isolated sample was monitored throughout the entire test cycle. The temperature chamber is outfitted with a safety purge system in the unlikely event that all samples leak at the same time.

The samples are small in size, so the volume of these 12 isolated samples is much smaller compared to the volume of the walk-in temperature chamber. Extra safety considerations were taken to ensure that the pressure transducers used to monitor pressure are intrinsically safe and piped to each sample inside the chamber using stainless steel tubing and compression fittings.

The team has begun data analysis of the test results and drafting the final report.


Data logging configuration using intrinsically safe pressure transducers for each test sample

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OTD
Operations
Technology
Development

Evaluating the Potential of Algae Capture of CO2

The goal of this project was to evaluate the potential of different carbon dioxide (CO2) capturing methods for delivery of CO2 to microalgae growth for production of RNG.

Project Description

Development of innovative CO2 capture technologies that can reduce the carbon footprint and convert to value added products are of interest to multiple stakeholders. One of the emerging CO2 capture technologies is algae-based CO2 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 experimentally evaluated the effectiveness and compatibility of several of these methods that have the ability to deliver CO2 to microalgae culture and enhance RNG production. Different microalgae species were evaluated for their growth and RNG production.

Deliverables

Deliverables for this project include identification of CO2 capturing methods that could deliver CO2 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 CO2 capturing techniques, and a final report on identification of methods for delivery of CO2 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 CO2 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

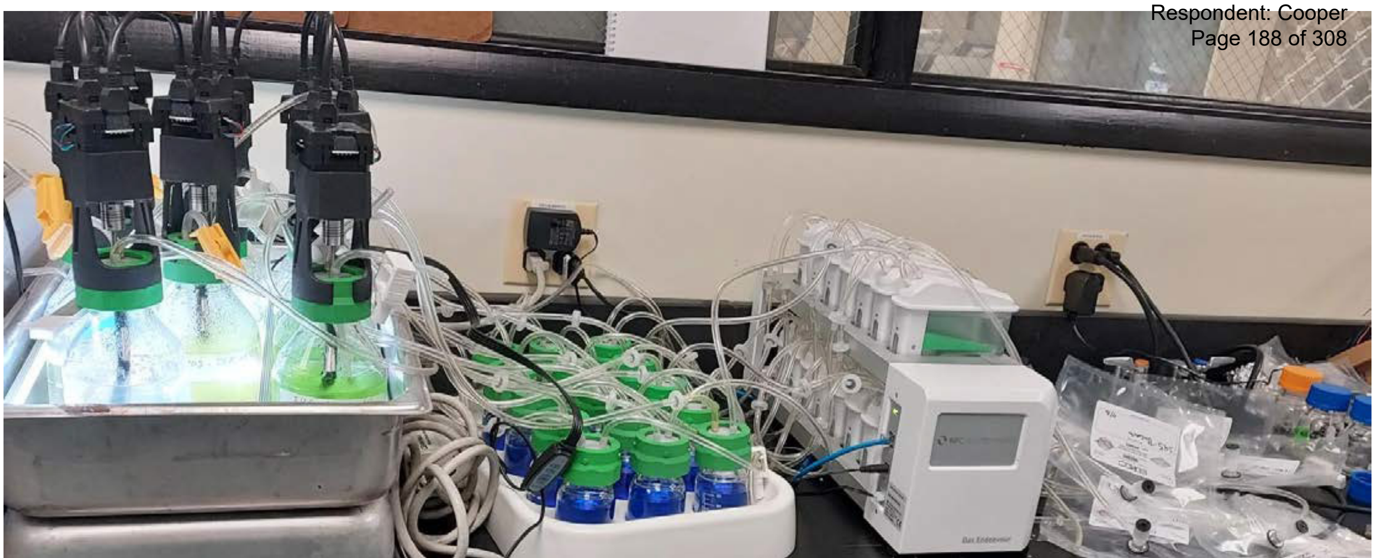
Microalgae are known to produce biomethane. In addition, the biomass produced from algae can also be used as a feedstock to obtain value-added products including production of biofuels and revenue generating commercial and pharmaceutical products. The important attributes of algae are that it efficiently utilizes CO2 as their carbon and energy source for growth, has higher photosynthetic efficiency, high CO2 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 CO2 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 CO2 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 CO2 capturing methods. Commercially available CO2 capturing methods are being identified and evaluated for delivery of CO2 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.

Results/Status

The present study identified several chemicals that could capture CO2 and deliver to microalgae culture for renewable energy production. Out of 20



Bioreactor setup and visible algae growth using CO2 capturing chemicals.

chemicals evaluated, 7 of them were able to capture CO2 with varying potential and effectiveness. Of the seven chemicals that showed CO2 capturing potentials, three of them Monoethanolamine (MEA), Ethylenediamine (EDA), and Dipropylamine (DPA) were able to deliver the CO2 to the microalgae culture at varying concentrations without compromising cell growth.

Microalgae growths were observed with CO2 provided from EDA, DEA, and MEA at final concentrations up to 0.5%. CO2 delivered from the bicarbonate solution also supported growth of many microalgae species. The highest growth on bicarbonate solution was observed for UTEX 246, UTEX 90, and Aphanothece sp UTEX SP25.

Biogas production potential of the selected microalgae species and the CO2 delivery solvents including bi-carbonate solutions were evaluated in a bioreactor under microaerophilic conditions. Although the micro-algae showed growth in the bioreactor with all selected CO2 capturing solvents, detectable methane production was not observed other than oxygen and nitrogen gases. This is likely due to the lack of genetic determinants of microalgae species to convert the CO2 into methane or due to the methane production inhibitory effect of microalgae metabolites.

Future research should be focused on harvesting biomass and its use for anaerobic digestion using bacterial culture if biomethane production is desired. In the absence of oxygen, bacteria could break down the organic matter of algae biomass and produce biogas.

To evaluate the biofuel production potential, the microalgae cultures grown in bioreactors in the presence of CO2 delivering solvents were used for Fatty Acid Methyl Ester (FAME) analysis. Analysis of the FAME profile helps to identify the strains with the highest biofuel production potential based on the yield and quality of lipids.

The cells were harvested by centrifugation and the dried biomass were subjected to lipid extraction. The lipids were then converted into FAMEs through a transesterification process. The FAMEs were then identified and quantified using gas chromatography. Analysis of FAME production indicated some microalgae species, such as UTEX 246 grown on CO2 delivered from EDA, showed the highest FAME production compared to cells grown on bicarbonate solution. This suggests that biofuel production is enhanced more when microalgae species are grown on CO2 delivered from the capturing chemicals.

In conclusion, this study identified solvents such as EDA, DEA and MEA as CO2 capturing and delivery methods to microalgae cultures for renewable energy production. The findings from this project will contribute to Greenhouse Gas (GHG) emission reduction by decreasing the carbon footprint from gas fired plants while simultaneously producing renewable energy and value-added products from microalgae cultivation.

This project is complete. The final report on Evaluating the Potential of Algae Capture of CO2 was completed and released to OTD member in September 2024.

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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 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.

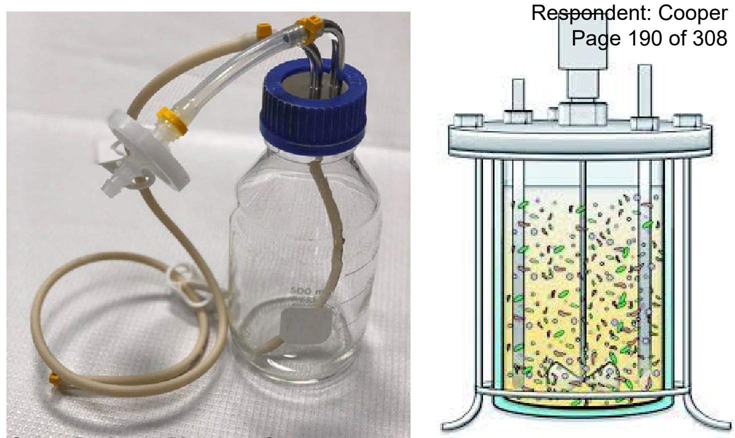
Results/Status

The team gathered 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.

The initial food waste biogas experiment to develop a robust inoculum was started in the first quarter of 2024. Foods containing arsenic (Brown rice, multigrain bread, apple/apple cores) terpenes (lemon and orange peels), complex sulfur compounds (onion peels and asparagus), complex carbohydrates (black beans), and other components (spinach, pine nuts, and green peppers) were blended into a slurry and introduced into 500 mL bottles containing a minimal nutrient medium. Nine milliliters of mixed municipal waste digestate was introduced as a source of microorganisms.

A sample containing only cellulose was used as a reference because it has a known methane production curve. A Food Waste + Cellulose sample was included to help diagnose issues with microbial community in the event that the food waste sample did not produce methane in the expected manner.

Early indications show the food waste and food waste + cellulose samples did not produce methane as expected. After aggressive gas production in the first two days, the food waste containing samples have been dormant. The cellulose sample produced gas as expected, slowly over the course of a few weeks.



Serum Bottle and Bioreactor Setup

The team modified the experiment by using a more diverse inocula, testing digesters with varying organic loads, and actively managing the pH during the first weeks of incubation. Actively managing the pH through the first weeks of digestion extended the fermentation phase and provided a more appropriate environment for methane producing microbes.

A digestion experiment is underway to screen for limonene contamination in gas produced from citrus peel waste. The team set up five one-liter digesters for this test. Initial results from mixed food waste containing citrus peel show no terpenes (cymene, or limonene) were detected in the biogas produced.

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OTD Operations Technology Development

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

Accurate measurement is the first step towards demonstrating credible reductions of methane emissions. Veritas is designed for this explicit purpose. Veritas provides protocols for each segment of the natural gas industry to measure methane emissions in a consistent and comparable way.

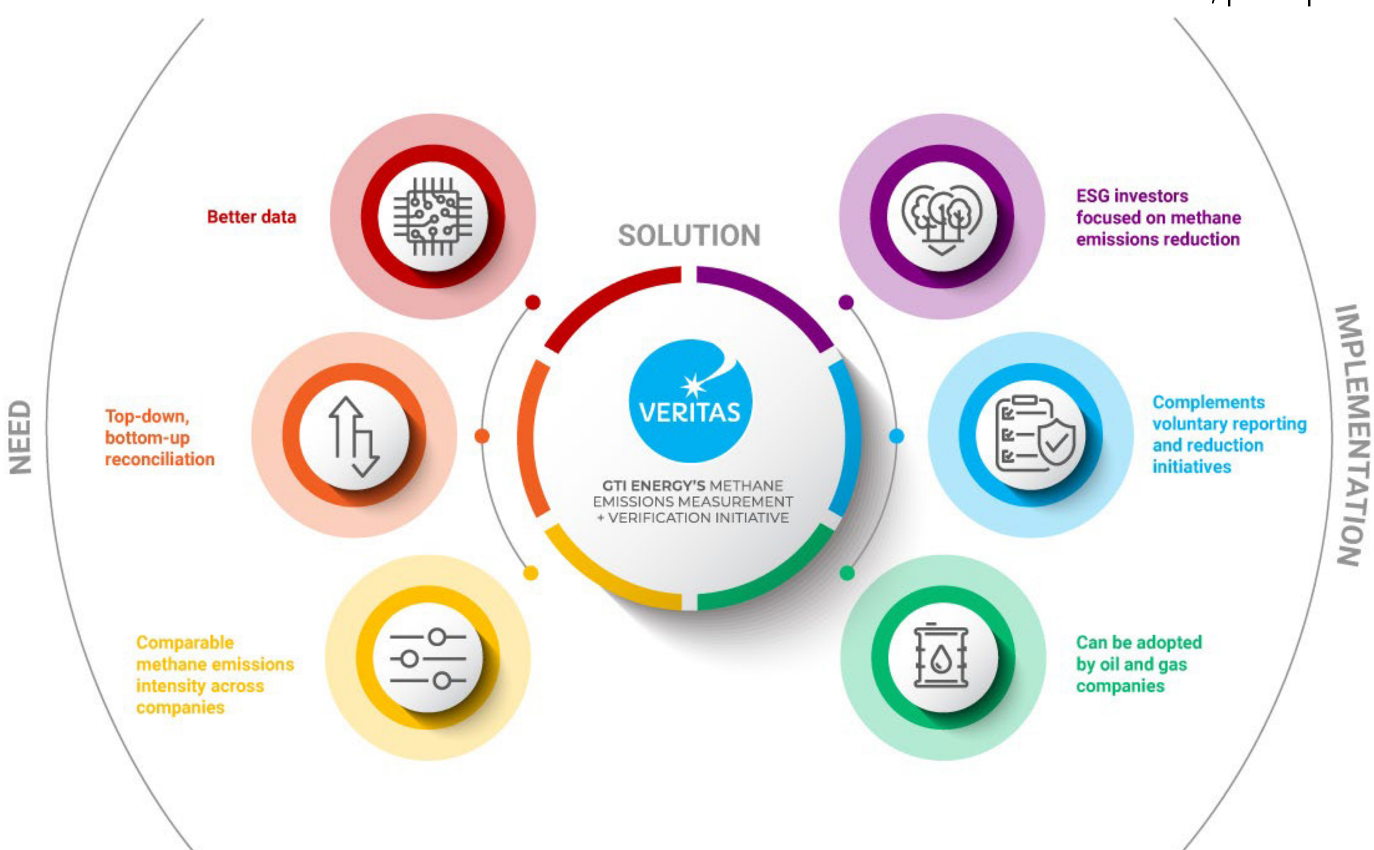
Deliverables

Deliverables so far have included publishing the protocols, developing the website, a whitepaper on project learnings, published documents addressing uncertainty in emissions measurement and quantification and data collection, and a communications strategy to facilitate stakeholder awareness and understanding.

Benefits

Widespread adoption of the Veritas protocols will result in consistent, trustworthy data that investors and other stakeholders can rely on. 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



Veritas is a standardized, science-based, technology-neutral, measurement-informed approach to calculating and reporting methane emissions.

in certification schemes, and meet import or procurement requirements that are tied to methane intensity more effectively.

Technical Concept & Approach

Veritas is an ongoing initiative, and OTD funders participate in several ongoing efforts, such as:

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 the 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/Status

Veritas Version 1 was published in February 2023 and Veritas Version 2 of the protocols was published in December 2023. (https://veritas.gti.energy)

The Veritas protocols have been tested and refined by industry leaders and cover all segments of the natural gas supply chain – upstream, midstream, and distribution. These technology-neutral protocols provide practical tools to accurately measure total emissions, helping companies to enhance efficiency, strengthen operations, and reduce waste.

To develop the protocols, GTI Energy worked with a diverse group of stakeholders to ensure the methodology is widely accepted and adopted, including academics, environmental NGOs, companies, investors, policymakers, and vendors. By publishing, updating, and refining these proven protocols and making them open-source, Veritas delivers a straightforward, results-oriented approach for companies to demonstrate progress on methane emissions reductions.

Protocols for Veritas Measurement and Verifications Initiative include:

Measurement & Reconciliation: Describe how to take measurements and reconcile emission-factor inventories with actual measurements.

Methane Emissions Intensity: Define methane intensities

Supply Chain Intensity: A comprehensive framework for estimating total methane emissions intensity across a user's supply chain

Assurance: Provide guidance for verifying emissions inventory.

GTI Energy will maintain these protocols as open-source, technical tools that can be deployed and operationalized by different stakeholders around the world. The open-source process encourages broad participation and observation of protocols to drive best practices. For example, the Veritas Protocols were updated based on stakeholder testing and feedback. As measurement and detection technologies become increasingly available, Veritas Version 2 offers a simplified framework to evaluate and respond to the mounting volume of data on methane emissions.

The Veritas Protocols include Upstream Protocols (Production, Gathering and Boosting); Midstream Protocols (Processing, Transmission and Storage, and Liquefied Natural Gas (LNG)); Distribution Protocols (Distribution).

The team held multiple webinars including: GTI Energy Future Focused Webinar: Exploring the Evolving Landscape of EPA Methane Emissions Reporting and GTI Energy Future Focused: Veritas and OGMP 2.0: Tools for Real-World Methane Reduction

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Evaluation of Current Advanced Mobile Leak Detection Systems

A variety of commercially available Advanced Mobile Leak Detection (AMLD) Systems are used for routine leak surveying in distribution systems. With sponsor guidance and participation, a selected set of these systems were field tested to compare performance in a blind study.

Project Description

The variety of AMLD technologies and their use, emphasized in the Protecting Our Infrastructure of Pipelines and Enhancing Safety (PIPES) Act of 2020, created the need for an evaluation of these systems. The goal of the project was to develop a framework for evaluation of different technologies, including statistical analysis methodologies. This project conducted field testing with highly senstive AMLD systems (pumped and open cavity laser) representative of typical approaches to determine factors impacting technology performance. The study conducted controlled testing to determine the effects of vehicle speed, leak rate, distance of measurement to leak, and wind speed on leak detection performance.

Deliverables

Deliverables for this project included:

- Single-blind controlled field test
- Quarterly reports
- Final confidential and public report

Benefits

Leak detection equipment and methodologies have been rapidly evolving for more than a decade. Operators across all natural gas segments need to understand the performance and limitations of these new technologies. The PIPES Act required all pipeline operators, including those in transmission and distribution, to adopt advanced leak detection technologies and practices to detect pipeline leaks. The AMLD platform has grown to include several commercial products, and it has become crucial to evaluate performance and determine use cases for these systems (i.e., regulatory leak survey or supplemental leak identification). Due to the time and resource requirements of fully implementing advanced technologies, comparison studies can provide operators with information to help with decision making.

Technical Concept & Approach

The scope of this project was focused in three key areas:

1. Field deployment planning
2. Field deployment
3. Data/Statistical analysis.

The research team structured the project with the following tasks:

Evaluation of as many AMLD technologies as possible. The effort focused on coordination with vendors for participation in the field study.

Locations of generated leaks at sponsor training facility

A test matrix was created based on the single-blind study method to evaluate AMLD system performance in which:

- The team conducted a single blind field study in collaboration with one sponsor utility. The leaks and locations were hidden from the AMLD systems and marked via GPS/GNSS device prior to the start of sampling each day.

- The AMLD technology vendors were asked to survey a defined area each day that included existing, graded, non-hazardous leaks. To neutralize differences in leak plume characteristics the technologies were deployed to the same areas and leaks on each day of testing.

- Six leak sizes or bins were used to establish probability of detection statistics.

- A statistical analysis and final report were written based on the data collected in the field deployment.

High flow sampler connected to tarp enclosure over a simulated leak

Results/Status

The project focused on evaluating detection capabilities of four AMLD devices: two pumped systems and two open cavity laser systems. Controlled release testing was conducted at a sponsor training facility and an open field parking lot to test various factors and affecting detection rates, including leak rate, distance from leak, and vehicle speed.

Each of these parameters influenced the detection rates demonstrated by the AMLD instruments; however, a combination of these factors significantly affects the detection performances. Higher flow rates of the leak, lower distance from the leak source, and lower vehicle driving speeds all contribute to a higher probability of detection (POD). Alternatively, a worst-case scenario with a low POD would involve a lower flowing leak, a larger distance from the leak source, and a faster driving speed. The instrument sensitivity also impacts the probability of detection, where a higher sensitivity and response leads to a higher POD. Improvements in sensors increase detection performance, however this could lead to more false detections, where the device indicates a leak, but a leak is not found.

Several challenges were presented throughout the course of this project. Each device had a different data output, and therefore required different data analysis scripts to interpret, clean, and compile the data. A set of operational limitations on speed, distance, wind and detection thresholds were evaluated and presented.

This study did not evaluate emission rate estimation, but rather focused on leak detection capabilities of some AMLD devices. Future investigations may involve further analysis of some of the parameters tested in this study or other factors such as wind and placement of the instrument on the vehicle.

The final report on evaluation of current advanced mobile leak detection system was completed and released to OTD members in September 2024.

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Optical Gas Imaging and Handheld Laser Methane Detectors for Large Leak IdentificationOptical Gas Imaging (OGI) and handheld laser methane detectors for large leak identification

The purpose of this study was to evaluate Optical Gas Imaging (OGI) cameras and handheld laser methane detectors (HLMD) for use in identifying large leaks in natural gas distribution systems.

Project Description

The project focused on a head-to-head comparison of the ability two methods, Optical Gas Imaging (OGI) cameras and handheld laser methane detectors (HLMD), to identify leaks on higher pressure assets. To accomplish that the project focused on planning and execution of a detailed field laboratory campaign followed by detailed data analysis. Testing was developed to simulate city gates, high pressure mains, industrial meters, or other higher-pressure assets.

Deliverables

Key deliverables for this project included a detailed test plan/matrix for testing at Methane Emission Technology Evaluation Center (METEC), an organized database of information collected, and a final report.

Benefits

Across all segments of the natural gas industry, there is an increased need to explore all options of reducing real-world methane emissions from assets. Identifying methods that offer quick scanning and potential identification of the largest leaks on assets can prioritize repairs for companies and quickly reduce their actual methane emissions with minimal impact to operations.

Technical Concept & Approach

Specific tasks in this project included:

Field Test Planning

This task focused on developing the test matrix and coordinating the tests with the METEC facility personnel.

Field Laboratory Testing

The project team conducted testing over a one-week period at the METEC facility in Fort Collins, CO. Tests included multiple blind operators to ensure that differences in operator capabilities are examined. Leaks were generated on different types of equipment and in at least six different leak size bins to fully explore instrument performance.

Statistical Analysis

During this task, the project team organized and prepared data for analysis then applied the analysis techniques developed in OTD Project 7.20.b. The team also explored the appropriateness of the analysis and determined if additional examinations were needed.

Results

Across different segments of the natural gas industry, there has been a need to find viable and effective ways of reducing methane emissions. Two methods of identifying methane emissions have been in commercial use for years, the optical gas imaging (OGI) and the handheld laser methane detector (HLMD). Both instruments work at a distance from leakage release points, and both require survey technicians to conduct the leak survey.

Testing was performed on both technologies at a research facility and a third party collected and analyzed data from each tool independently. Based on literature in the field, it was expected that OGI would find only the largest of the leaks, missing smaller leaks, and that HLMD would find all sizes, both large and small.

Results demonstrate that HLMD did find most of the leaks, regardless of size. OGI also found most of the leaks, including those categorized as small. Essentially, there was no difference in performance between HLMD and OGI with respect to leak detection for this test and both leak survey instruments demonstrated the ability to detect above-ground leaks with high confidence under the conditions studied (e.g., low wind speeds, mild ambient temperatures).

Separators


Tank

Scrubbers

Wellheads

This finding suggests that the performance of HLMD and OGI might be attributed to outlying factors, such as operator expertise level and weather-related testing conditions. Future studies should consider applying a broader range of user experience, wind conditions, and temperatures to more definitively detail possible differences in performance between both devices. Such studies could help inform which detectors distribution companies choose in various situations.

This project is complete. The final report of Optical Gas Imaging and Handheld Laser Methane Detectors for Large Leak Identification was completed and released to OTD members in January 2025.

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Open Hydrogen Initiative

Open Hydrogen Initiative (OHI) is an international research consortium with the expressed intent of laying the foundation for technology-neutral hydrogen and clean fuel markets. Through this, all forms of hydrogen production can be compared on an apples-to-apples basis, void of technology or feedstock-based biases.

Project Description

Carbon intensity information is crucial to enabling credibility and scale in clean fuel markets. However, contorted emissions accounting can also be weaponized to disadvantage various forms of clean hydrogen production. OHI will provide a level playing field for the comparison of hydrogen production pathways and help operators better understand where to invest in technologies that meet their decarbonization goals. This work arms the industry with the credible, transparent, and science-based tools necessary for underpinning clean hydrogen production, consumption, policy, and investment.

In Phase 2, the project prioritized expanding the OHI toolkit to include pipeline transportation and ammonia production, further refining the toolkit, conducting a public comment period, developing model contracts for clean fuel offtake, engaging in educational advocacy with regulators and policymakers, and convening industry stakeholders.

Deliverables

Deliverables for this project included the development of model offtake contracts for clean fuels and new LCA modules covering pure hydrogen pipelines, ammonia production, gaseous hydrogen trucking, liquefaction, and liquid hydrogen trucking. The project also convened monthly industry meetings and hosted three special policy sessions to advance regulatory alignment and stakeholder engagement.

Benefits

OHI will provide a level playing field for the comparison of hydrogen and clean fuel production pathways and help operators better understand where to invest in technologies that meet their decarbonization goals. This work arms the industry with the credible, transparent, and science-based tools necessary for underpinning clean fuel markets. The usage and adoption of the OHI toolkit will arm market participants with consistent and trustworthy data, supporting a more technology inclusive market.

Technical Concept & Approach

Specific tasks in this project include:

Advanced Technical Solutions

In this task, the team will leverage technical expertise to continuously enhance the existing solution, broaden the influence of the OHI toolkit, and bolster confidence and credibility. The team will expand the OHI toolkit to include both ammonia production & H2 transport, host a public comment period on OHI toolkit & supporting documentation and incorporate feedback, continue to address bugs in the OHI toolkit, improving functionality and user experience through on-going patches and version, and provide on-going technical support for organizations looking to utilize the OHI toolkit.

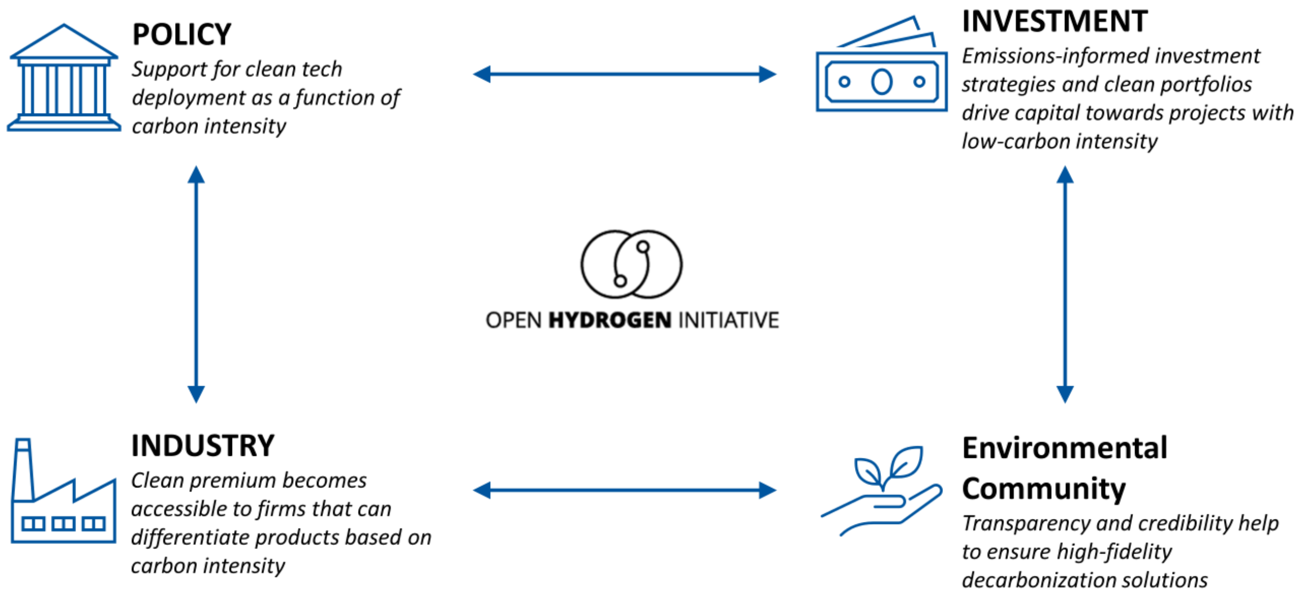
Market Infrastructure

This task will focus on building the market infrastructure needed to support widespread adoption of the OHI carbon intensity (CI) methodology. The project team will develop standardized clean hydrogen contracts, CI-based Environmental Attribute Certificates (EACs), and carbon intensity-informed pricing benchmarks. This work aims to move the industry beyond color-based classifications and position OHI as a central framework for certification and trade in global clean hydrogen markets.

Awareness & Education

This task will elevate OHI's research to US regulators and stakeholders with a particular focus on 45V guidance, coordinate with international reg-

Credible Carbon Intensity Calculations are a Market Accelerant



ulators and researchers to increase compatibility between the OHI toolkit and existing/new regulations, educate policymakers on behalf of OHI stakeholders regarding technology-neutral approaches to supporting clean hydrogen deployment, and improve harmonization between the OHI toolkit and research being conducted by ISO and IPHE.

Engagement

This task will bring together key stakeholders to exchange insights, address shared challenges, and accelerate the development of clean fuel markets. The project team will host industry events, targeted roundtables, and technical workshops, while facilitating ongoing technical meetings and quarterly board sessions. Additional efforts will focus on engaging the financial community and strengthening coordination between the OHI cohort, Hydrogen Hubs, and aligned coalitions.

Results/Status

The OHI coalition played a critical role in harmonizing market standards, working alongside many organizations and establishing assurance programs that will be instrumental in helping clean hydrogen producers earn a premium for their low-carbon products - another step toward creating market mechanisms that reward clean hydrogen producers for their leadership in emissions reductions.

OHI's influence stretched across the globe, with participation in more than 15 events across North America, Latin America, Eastern Europe, and the Middle East. The OHI coalition continues to grow, with nine new members joining our ranks in the last 12 months. The public comment period helped ensure our efforts reflect a broad range of industry perspectives, reinforcing OHI's role as a trusted resource.

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OTD Operations Technology Development

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 affecting corrosion potential 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 external corrosion potential based on soil conditions. The assessment will assist in the decision making of mitigating the threat through 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, moisture content, and other soil properties. The outcome of the project develops a corrosion potential model in a web-based software for risk assessment. Results from field data can 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.

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

Specific tasks in this project include:

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 severe 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 other soil and environmental conditions. Develop a user interface for data entry and search.

Evaluate Soil and Environmental Parameters

Correlate measurements of soil parameters to predict a corrosion potential estimate. Examples of field data include soil moisture content, pH, resistivity, drainage characteristics, chloride and sulfite levels, and soil Redox potential. Many of these parameters can be obtained from existing soil survey data.

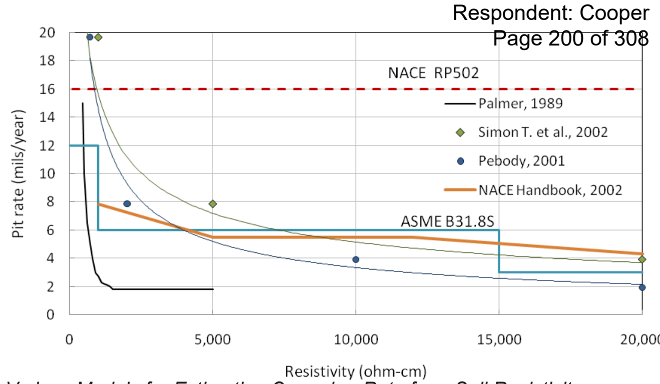
Incorporate Data in a Web-Based Risk Management Program

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 developed 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.



Various Models for Estimating Corrosion-Rate from Soil Resistivity

The team started by conducting a causal analysis of the parameters affecting soil movement and, consequently, pipelines failures. The team developed a preliminary risk model that assesses soil interaction (i.e., geological and geophysical forces) which result in soil movement and, consequently, belowground pipe strains.

Data obtained from the NIST study and provided by utilities about soil conditions were processed to fit a set of probability distributions. Python routines were developed to process and analyze the data, including fitting probability distributions for each soil characteristic.

A Bayesian network analysis was developed based on this framework using 'Agena Risk' program. The functions and estimated initial distributions of input parameters in the program were based on data from the literature, earlier corrosion studies (e.g., NIST study), and utility records of corrosion failure data.

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OTD Operations Technology Development

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

Specific tasks in this project include:

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.

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.

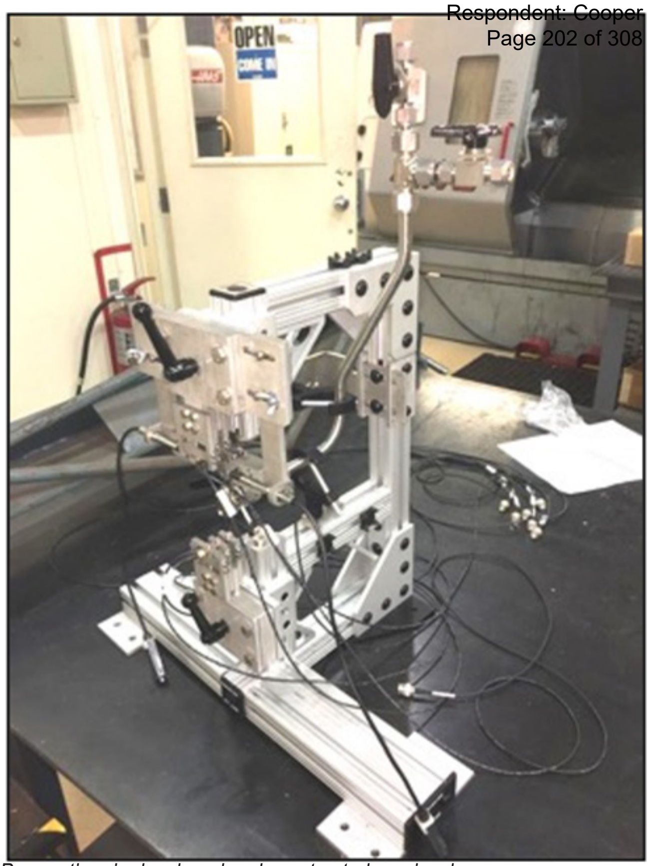
Develop Material Property Database & Perform Ultrasonic Signal Modeling

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

The project team completed the construction and assembly of the rigs. The post-machining analysis determined that most of the components required additional dimensional correction. An iterative process was utilized to address machining issues such as improper tapping hole sizes and machining countersinks. As the intricacies of the rig's physical design require that subassemblies interlock with each other, each component had to be exactly the dimensions specified in the software design. Post-assembly analysis revealed that the ultrasonic transducers contact the ¼" thick specimens at four distinct points. Fixing component dimensions so they fit properly required multiple iterations while being careful not to overwork the metal.

The team also worked on integrating the control software with the three-test rig system. Analysis of the existing test rig software solution revealed that it was not written in a modular and scalable format, which made seemingly minor changes significant due to the cascading effects throughout the system. Most of the requested user interface changes have now been completed.



Permeation rig developed and constructed previously.

Additionally, the project team completed preparing specimens, machining of all the MDPE, B-MDPE, and HDPE samples. The specimens will be saturated with the C6, C8, and C10 hydrocarbons prior to permeation testing.

The project team has conducted multiple shakedowns to validate the proper operation of the 3-test rig system prior to conducting testing at high temperature. Issues discovered during the latest shakedown continue to be analyzed and addressed by the project team. Additionally, the team will work with GTI Energy's analytical chemical lab to acquire the heavy hydrocarbons so that permeation testing may begin upon test rig shakedown completion.

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OTD Operations Technology Development

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.

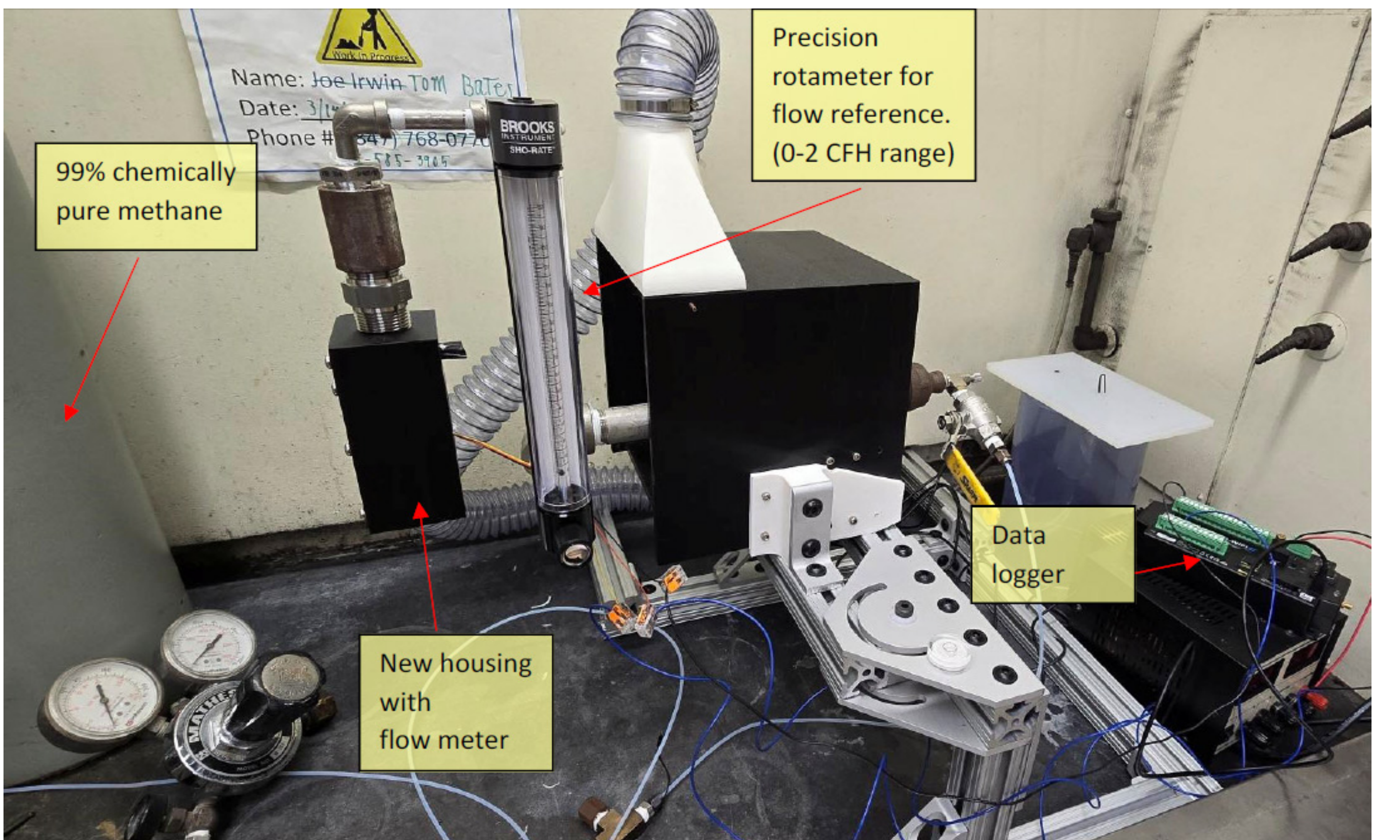
This Phase 1 effort will focus on the development of an instrument that can be deployed to quantify the number of times the equipment vents to atmosphere and the volume of gas released each time.

Deliverables

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

Limited 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



Sensor assembly and flow test setup

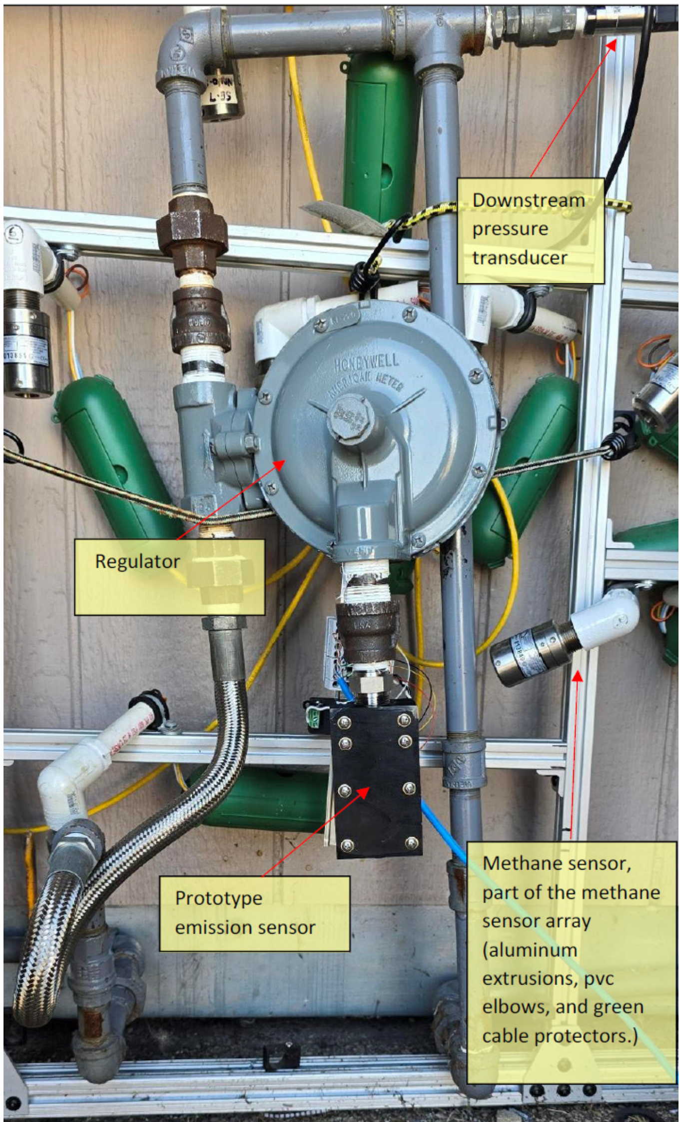


Image showing the outdoor testing setup

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 in 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

The project team has completed the programming for the sensor assembly. However, due to recurring difficulties with operating and communicating with the flow sensor manufacturer, the project team has chosen to use a different flow sensor going forward.

The team has received, integrated, and calibrated the new flow meter. The project team has completed indoor testing with compressed air and is now performing outdoor testing with live gas. Continued improvements to accuracy and reliability are being made as testing progresses. The project team will continue to improve the script and work to achieve a more consolidated, reliable, and durable prototype in preparation for the next phase of the project.

Status

Looking forward, the project team will complete testing with inline meters; further improve sensor script; design PCB and consolidate wiring; integrate a battery pack; design or source weatherproof housing for the battery and datalogger; source weatherproof cabling to connect the sensor assembly to the battery and datalogger; and write the Final Report.

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OTD Operations Technology Development

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 potentially 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 detect outside gas leaks using a stationary methane sensor will provide quicker notification compared to current leak detection processes. Early detection is key to safety, improved effectiveness, and reduced costs associated with an emergency.

Simulation of below-ground leaks through soil during outdoor testing.

GTI Energy's Pipe Farm, which will serve as the location for the outdoor test.

Manufacturers and vendors in the leak detection market offer multiple types of equipment and solutions to perform the federal requirement of leak surveys over gas facilities. Since natural gas incidents still occur after these leak surveys are performed, an additional layer of leak detection that can provide continuous (24 hour) surveillance to detect and notify of leaks will further improve safety.

There is demand for an Advanced ONGD, and current advancements in methane sensors focusing on low-power (for long life battery use), high accuracy (no false positives), improved detectability (for higher ppm), and improved durability in environment conditions (allowing for long-life in an outside environment) provide a development opportunity for a new product. Many of the newer methane sensors on the market are significantly more advanced than 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 of the methane sensors have been delivered and testing has begun according to the approved test plan.

Sensor Performance Testing

Accuracy testing of the sensors has begun, exposing the sensors to calibrated test gas mixtures as specified in the test plan. The sensors are being tested with hydrogen (50-200 ppm), 20% hydrogen/80% methane blends (50-200 ppm), natural gas/methane (50-200 ppm), and propane (50ppm). Propane is included to evaluate the sensor's behavior to a gas outside of its intended target.

Environmental Testing

Outdoor testing of the sensors has commenced at GTI Energy's pipe farm, testing the sensor's ability to detect both above-ground and below-ground leaks. The testing includes simulation of various leak scenarios such as below-ground leaks through soil substrates, above-ground fitting leaks, and simulated regulator vent emissions. Weather conditions are being logged throughout the testing period to capture performance under various environmental conditions.

Testing will be extended into the winter months (Q1 2025) to assess the sensors' performance under cold environmental conditions.

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Operations Technology Development

Effect of H2 On Odorants in Gas Blends

Researchers determined the impact of hydrogen on odorization to ensure that this safety measure is not degraded through odor fade or preferential leakage.

Project Description

Odorants used in natural gas distribution systems are 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 addressed 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 delivered 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.

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 was reviewed to determine representative laboratory setups of odorant application in hydrogen blending. The setups were representative of typical leaks in gas distribution, like threading components, couplings, or connections on cast iron. Findings were presented to the project sponsors to decide the most useful leak setup and test procedures.

Laboratory Evaluation of Leaks

The work in this task included recreating 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) were obtained and tested in a leak rig. The concentrations of the source gas, as well as the leaked gas were then measured using instruments, such as a gas chromatograph, to determine whether there were any effect on the ratio of hydrogen to methane or odorant concentration. In addition to the quantitative analysis, the presence or absence of odor were noted by the experimenter as a secondary confirmation of the presence of odorant. The experimenters were pre-qualified using a natural gas scratch sniff card each day testing is performed.

Lab Evaluation of Odor Fade

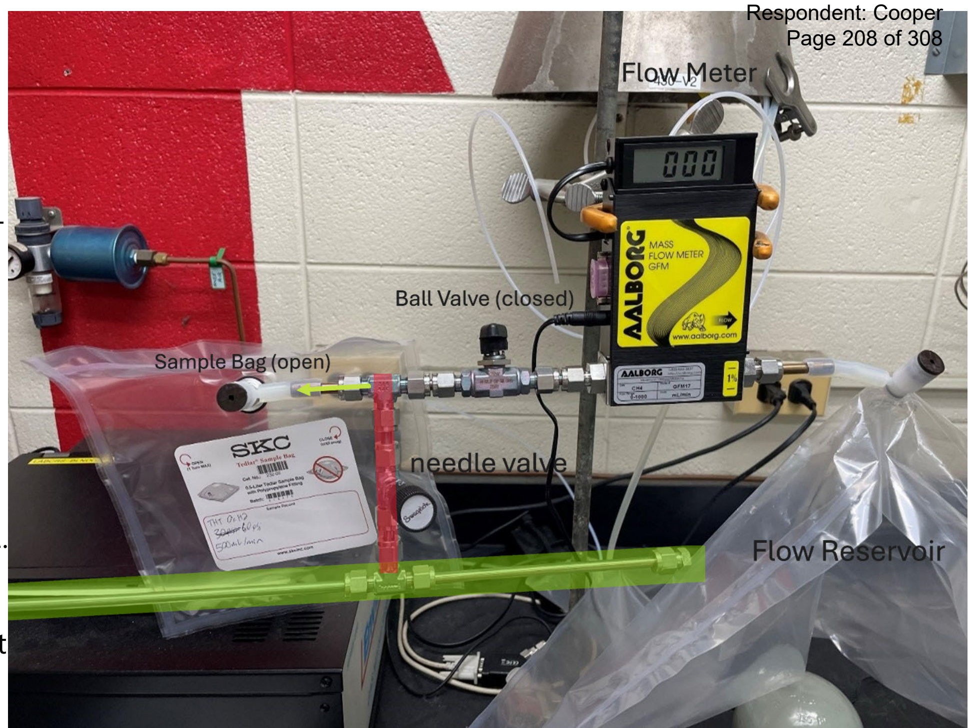
This task investigated the effects that varying concentrations of hydrogen blended with natural gas have on odor fade in stagnant pipes. Hydrogen's effect on both THT and TBM were investigated.

Additional Risks Evaluation

This task evaluated 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 project team conducted a laboratory evaluation focusing on possible leakage of hydrogen at pressures and leak rates commonly seen in gas distribution lines. Pressure within the test rig varied from 5 psi to 60 psi, and the leak rate was adjusted from 10mL/min at each pressure, up to 500mL/min. Based on sponsor input, two of each of the following gas blends were ordered containing 0% H2, 5% H2, and 20% H2. One set of gases was odorized with 2.5 ppmv tert-butyl mercaptan (TBM), and the other set with 2.5 ppmv tetrahydrothiophene (THT), two commonly used odorants in North America.



Testing Rig in Sampling Position

The effect of hydrogen in gas blends on odor fade was also monitored throughout this project by analyzing the gases at the start and end of the test period. Leak test results indicate there was no change in hydrogen to odorant ratios in the leaked gases compared to the source gases regardless of hydrogen concentration or odorant used. Only a few of the leak test results had hydrogen recovery when compared to the certified concentration higher than the recovery of odorant when compared to the concentration of the source gas corrected by the loss-rate determined from the initial and final concentrations.

Of these outliers, none were outside the margin of error for the Gas Chromatography (GC), and there were no scenarios tested where the concentration of hydrogen appeared to directly correlate to a decrease in odorant. Additional testing confirmed the variances in recovery seen were likely due to a shift in sensitivity by the GC on the date the samples were analyzed. This suggests that there is no preferential leakage of hydrogen in relation to odorants at pressures one would expect to see in distribution lines and at leak rates below 500 mL/min. Consequently, it is unlikely that a properly odorized natural gas and hydrogen blend would have lower detectability by smell for the average person than a traditional natural gas leak, according to the data from this task.

The project team also evaluated of odor fade. The gas blends odorized with TBM experienced odor fade at a lower rate than the control blend containing no hydrogen. This suggests that hydrogen concentrations up to 20% in natural gas will not influence odor fade when a gas is odorized with TBM. While all test gases odorized with THT showed odor fade over the testing period, no correlation between loss of THT concentration and change in hydrogen concentration was observed.

Since the loss of odorant did not increase directly with the concentration of hydrogen, it is reasonable to assume that the odor fade was due to factors other than hydrogen blending. Common causes of odor fade are adsorption and absorption, both of which may have occurred within the regulator.

The measured recoveries of hydrogen and odorant were then compared to determine whether there was any preferential leakage. The recoveries of both the odorant and the hydrogen from the bag samples when compared to the known quantity in the gases suggest that there was no preferential leakage of hydrogen at any pressure (<60 PSI), or leak rate (<500mL/min) tested.

This project is complete. The final report of Effect of Hydrogen on Odorants in Gas Blends was completed and released to OTD members in January 2025.

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Operations Technology Development

Advancing Hydrogen Leak Detection and Quantification Technologies Compatible with Hydrogen Blends (US DOT PHMSA)

The objective of this project is to understand and advance sensing technologies in Hydrogen/ Natural Gas Blends. Evaluations will be done to determine the efficacy of existing sensing technologies in blends with up to 20% hydrogen.

Project Description

The purpose of this project is to advance leak detection as hydrogen is introduced into natural gas infrastructure. The project team will evaluate various leak detection equipment currently being used by natural gas pipeline operators and provide guidance and analysis on how hydrogen impacts their use and protocols.

Deliverables

The deliverables of this project will include a literature review, a leak detection system validation test plan, test results for both the laboratory and field-based tests, newly developed technologies or methodologies to detect leaks from pipeline infrastructure as hydrogen is added to the natural gas, and a final report.

Benefits

The findings of this project are crucial for advancing understanding of hydrogen and natural gas/ hydrogen blend leaks, ensuring that any leaks can be detected quickly and efficiently, reducing potential safety impacts caused by undetected leaks, and minimizing misinterpreted leak detection results causing an underestimation of the size and potential safety hazard of a leak.

Technical Concept & Approach

Specific tasks in this project include:

Understand Leak Dynamics and Identify Testing Scenarios

This task includes a literature review of the work done on the dynamics of a hydrogen/methane mixture when leaving a pipeline and the evolution of the subsequent plume; a survey of real use cases within the industry and a characterization of these scenarios (i.e., amount of hydrogen present). The project team also will provide technical test specifications to guide technology evaluation/development and identify methods for real life testing.

Evaluation Testing of Common Leak Detectors

The project team will evaluate the efficacy of commonly used gas detection technologies within mixtures containing varying amounts of hydrogen; acquire commonly used leak search tools within the industry and survey their pertinent specifications for comparison; evaluate in a laboratory setting the efficacy of such tools given varying amounts of hydrogen injection; and test the efficacy of such tools in the field given varying amounts of hydrogen injection.

Explore and Evaluate the Technology Readiness Level

The project team will develop an overview of potential detection paradigms to provide information regarding what sensors are required; conduct a literature review of sensing technologies available in the market and within academia; select promising technologies and perform benchtop testing; and engage with industry to field test these sensing technologies

Controlled Field-Based Evaluation Testing

The project team will formulate recommendations with regards to changes to work practices to best use leak search equipment; formulate a plan with regards to potential obsolescence of existing technology and equipment; and identify and advance the next generation of sensors required for leak search equipment.

Statistical/Data Analysis

For this task the team will acquire statistically significant data. They will conduct Analysis of Variance (ANOVA), which will be used to verify the representativeness of the datasets, especially across operators and sites.

Results/Status

The project team completed a literature review in three areas: dynamics of gas leakage regarding the interaction of hydrogen and other gases, existing leak detection methodologies and equipment used by utilities, and sensing technologies on the market and within academia. Based on the literature findings, the project team created a list of initial technical specifications and requirements for evaluation as well as additional specifications and requirements for future evaluation.

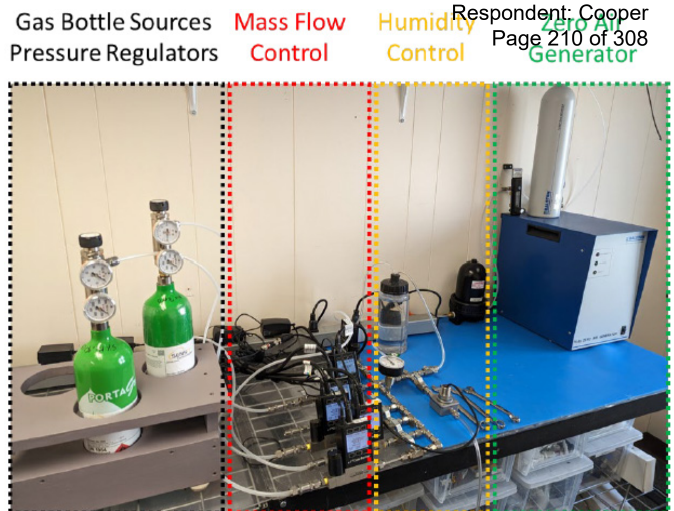
The evaluation framework, which will be used to evaluate the field and laboratory testing, was developed and focuses on two areas: laboratory testing under controlled conditions, and field testing with controlled leaks at three local distribution company training facilities with both underground and above ground leak sources. The results obtained during lab and field evaluation will drive the investigation on hydrogen/natural gas blends.

The project team identified four distinct major sensor groups of interest: flammable gas sensors, air toxic sensors, oxygen sensors, and hydrogen specific sensors. Each group will require slightly different evaluation protocols and target tests. The field-based portion of testing will be focused on three main scenarios: above ground meter leaks, below ground leaks, and indoor appliances (e.g., gas stove, water heater, etc.). Hydrogen injection mixtures ranging from 0 to 20 vol.% will be tested depending on each facility's capabilities.

In 2024, laboratory testing and field trials began. Two field trials were completed. Initial analysis of the data from the first field test saw no significant difference in leak detection for "larger leaks" that began underground but leaks with very small flow exhibited differences when blended with hydrogen. Leaks on meter sets and appliances did not have a significant leak detection difference regardless of leak rate. Initial analysis of the data from the second field test suggests that lower flow rate leaks with higher blend concentrations may impact detection performance, especially on belowground leaks.

The project team has also provided a preliminary assessment of functional gaps in various natural gas sensors and instruments when exposed to differing hydrogen concentrations. Some key initial results discussed are:

1. Gas leakage survey may be affected to a limited extent based on a maximum of 20% hydrogen blended with natural gas. Primary leak survey instruments use optical based sensors which are highly sensitive to methane and insensitive to hydrogen. As the hydrogen concentration increases, methane concentration decreases proportionally. As a result, the amount of methane detected will be lower. If the methane reduction is enough, detection of small leaks with low emission rates may be more difficult. This reduction can be most noticeable as blending reaches 20% hydrogen, yet it remains a preliminary finding due to ongoing field testing.



2. Leak investigation and personal protection equipment can be impacted. These instruments use a variety of sensors for different purposes and may have several different gas sensors within an instrument. The reaction to hydrogen varies widely and is dependent on the sensor technology, exposure concentration, exposure duration and the sensor manufacturer.

3. Hydrogen-specific or compensated sensor technology is currently under development at both fundamental and pre-commercial levels. However, the technology remains in its early stages. Information is limited due to the proprietary nature of technological development.

Laboratory testing is ongoing and is scheduled to be completed in 2025. An interim sensor package report was submitted to PHMSA. Analysis of data collected from the two field trials is in progress. A third field trial is scheduled for February 2025 and will complete the field trial portion of the project.

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Investigate Feasibility of Pipeline Thermographic Internal Inspection for Leak Detection

Researchers evaluated a novel in-line pipeline leak detection approach using infrared thermography. Practical tools for timely leak detection enhance safety and reduce methane emissions. While there are numerous methods for detecting leaks outside a pipe, leak detection from inside the pipe is a novel concept.

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 evaluated a novel approach to leak detection using thermal sensing and infrared thermography within a pipeline. If feasible, this approach could lead to the development of a tool for inline inspection (ILI). The concept focused 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 used thermal sensors to measure observable temperature differentials from within a pipe.

Deliverables

Deliverables included a literature review, results of CFD modeling, and findings of laboratory experiments.

Benefits

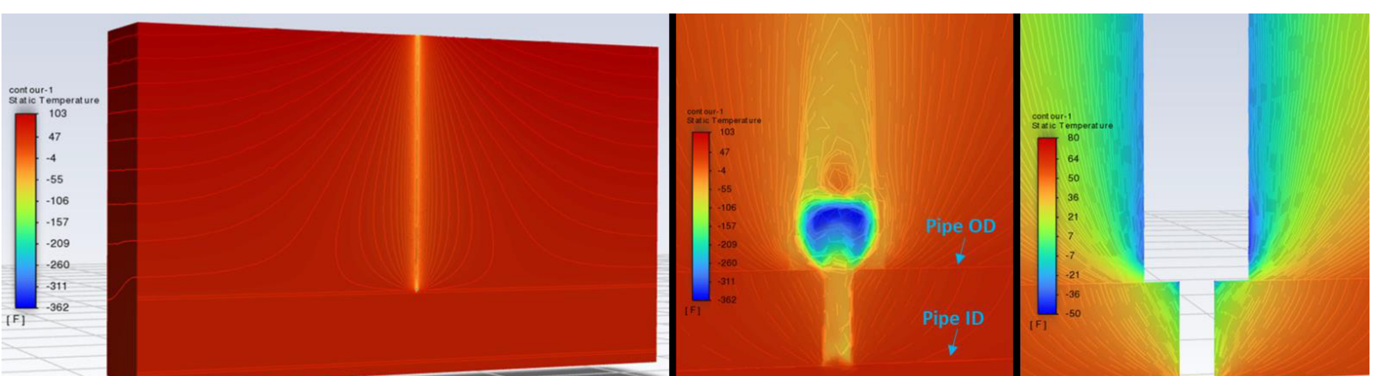
Practical tools for timely leak detection enhance safety and reduce methane emissions. If successful, this project could yield a novel approach to IR leak detection with ILI.

Technical Concept & Approach

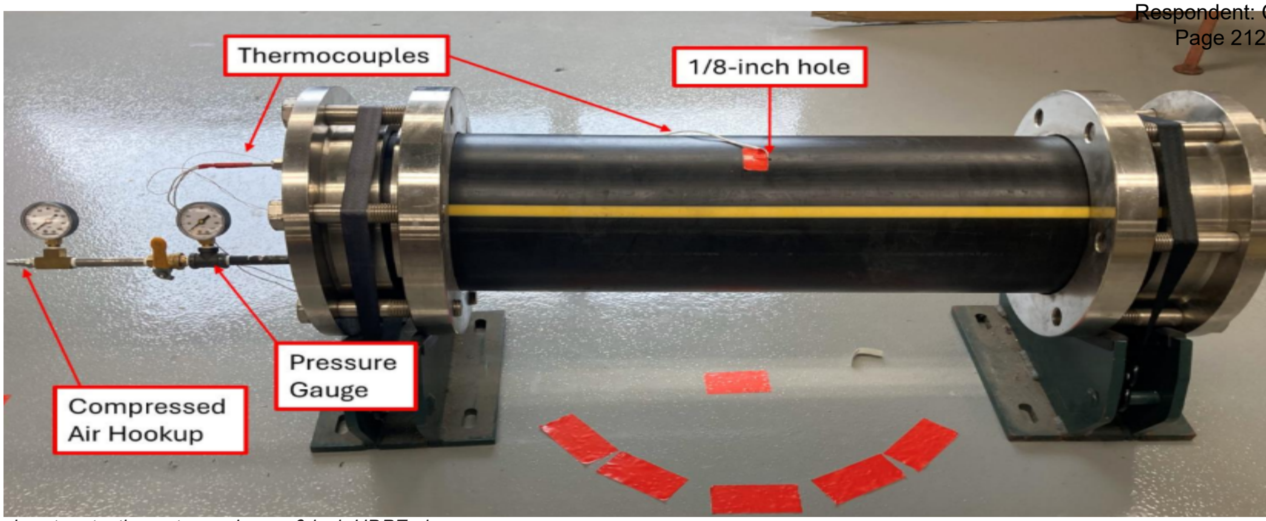
Specific tasks in this project included:

Literature and Product Review

Evaluated prior research and existing technologies that may provide insight into this approach. Though thermographic inspection is used in many settings to examine external surface temperature patterns, none were found to be deployed from within a pipe to detect leaks. Thus, the approach of using infrared sensing to detect leaks with internal inspection appears to be a novel concept.



Example of CFD modeling using a 10" steel pipe operating at 1000 psig and ambient air at 110°F with the CFD temperature contour (left), close-up view around the hole (center), and close-up view around the hole with no gas (right).



Laboratory testing set-up using an 8-inch HDPE pipe

Temperature Differential Model

A simplified, first order Computational Fluid Dynamics (CFD) model was generated to estimate the temperature differentials along the interior pipe wall in the region of the leak. Modeling simulated a buried pipe with a 1/8-inch leak hole at 150 psi and indicated a detectable cooling effect on the interior pipe wall at the leak.

Laboratory Test

Laboratory testing was conducted to measure temperature effects with an 8-inch diameter high-density polyethylene (HDPE) pipe and a 1/8-inch diameter circular hole to emulate modeling results. Tests were conducted at 50 psi with air. Thermal sensors were placed along the interior and exterior pipe surfaces near the leak. Results were compared with the thermal model. Inside the pipe near the leak hole were observable temperature drops of 1.8 to 3°C, with maximum drops of 2.5 to 4°C.

Results/Status

The project team evaluated a novel approach to detect leaks from within a pipeline by observing the temperature drop that occurs as gas escapes the pipe and expands. The team investigated the temperature effects of a leak on a pipeline through CFD modeling and laboratory testing.

CFD modeling analyzed the effects of various parameters on the cooling effect at the inside and outside surface of both steel and HDPE pipe where a leak was present. At similar pressure and conditions, the cooling effect on steel pipe is greater than with plastic, as expected. Ambient air temperature and pipe diameter did not have significant impacts on the cooling effect. Pressure, pipe material, and leak rate are key factors governing these effects.

CFD modeling and experimental results indicate that there would be temperature drop on the inside of the pipe sufficient to be detected using infrared (IR) thermography. These results suggest that thermal sensing could be used to detect leaks from inside the pipe with in-line inspection (ILI). Though the initial approach envisioned the use of infrared thermographic imaging, commercially available laser sensors would be well-suited to this application.

Future investigations into this concept could involve testing under different conditions and using temperature sensors of a type (such as laser) that might be deployable with an ILI system. Future work could also begin to characterize how thermal sensing might be applied for internal inspection by examining sensor types, modes of deployment, and information processing.

The final report on Pipeline Thermographic Internal Inspection for Leak Detection was completed and released to OTD members in August 2024.

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Optical Laser Gas Imager Monitor

This project will assist with technical guidance and evaluation of GeoTeknica's gas imaging technology.

Project Description

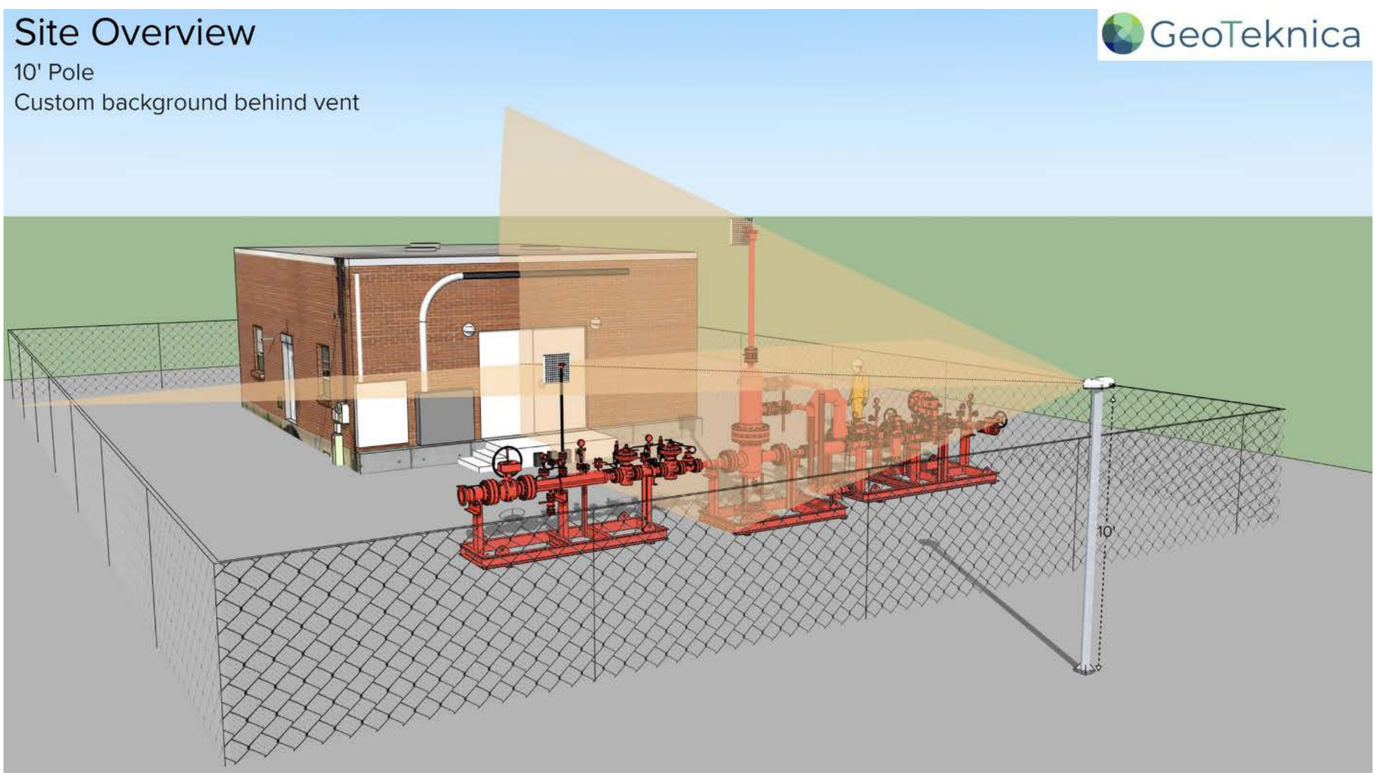
GeoTeknica is in the early stage of technological development of a high sensitivity optical gas imager (OGI) for use in continuous monitoring applications. This project will assist with technical guidance and evaluation of GeoTeknica's gas imaging technology.

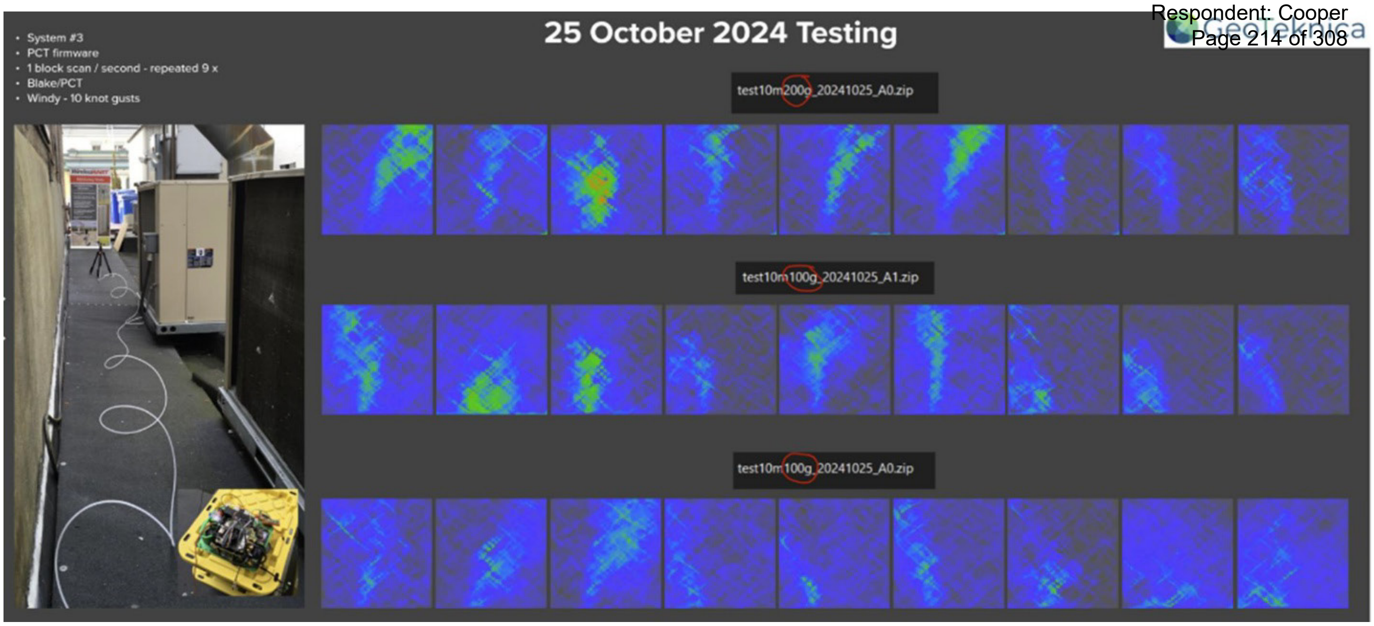
GeoTeknica has invented a new generation of active laser scanning methane imager with the advanced detection capabilities of leading LiDAR systems. GeoTeknica aims to commercialize this technology.

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 work with the vendor to provide recommendations on system design and requirements for the optical gas imager for fixed monitoring applications.





Benefits

Fixed continuous monitoring offers the capability to detect leaks on critical infrastructure as they occur, enabling responses 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:

Design Review

The team will confer with GeoTeknica as prototype development progresses and provide technical guidance.

Prototype (Laboratory) Testing

This task includes testing the prototype instrument in the laboratory. Initial tests will focus on controlled leak rates under indoor controlled conditions to better understand detection lower limits. Outdoor testing will focus on establishing detection limits with uncontrolled test conditions such as background, above and below ground.

Results/Status

The project team has been meeting with the developer to discuss design elements as prototype development advances. Alpha prototypes have been developed, and internal testing is in progress at the developer.

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Reliable Affordable Infrastructure for Secure Energy (RAISE)

RAISE equips stakeholders with a holistic understanding of the complexity and value of existing natural gas infrastructure systems, and provides actional recommendations on the research, technology development, partnerships and investments required to upgrade and evolve the country's gas infrastructure to advance safer and more reliable energy systems.

Project Description

The U.S. gas infrastructure network consists of thousands of miles of connected pipelines and storage facilities that help provide reliable, and affordable forms of energy in today's energy systems. Pipeline companies also delivered 75% of the natural gas used to generate electric power in the U.S. in 2023. With electricity demand continuing to increase significantly, understanding how to maintain, upgrade and modernize this extensive infrastructure network will be an important lever in energy system transition. 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).

Reliable Affordable Infrastructure for Security Energy (RAISE) focused on defining and capitalizing on the opportunity associated with upgrading existing natural gas infrastructure to accelerate deployment of emerging low-carbon fuels and decarbonization solutions while saving costs, minimizing environmental impact, and stimulating job creation and economic growth. RAISE 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 future energy systems must be reliable, safe, resilient, sustainable, and affordable.

Deliverables

The program deliverables are to publish regional case studies that assess the role of current and future gas infrastructure in the energy transition to net-zero emissions by midcentury, publish short-form research papers that educate stakeholders on the complexity and considerations of gas infrastructure in integrated energy systems, and to hold education workshops conducted with State Public Utility Commission (PUC) stakeholders.

Benefits

RAISE 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. RAISE is also an opportunity to build dialogue and collaboration across stakeholders including researchers, investors, operators and asset owners, and local communities.

Technical Concept & Approach

RAISE's program is divided into three key priorities and has an interactive web portal that houses up-to-date technological and regulatory developments and RAISE related research and webinars.

Demonstrate the need for existing and new gas and related energy-infrastructure

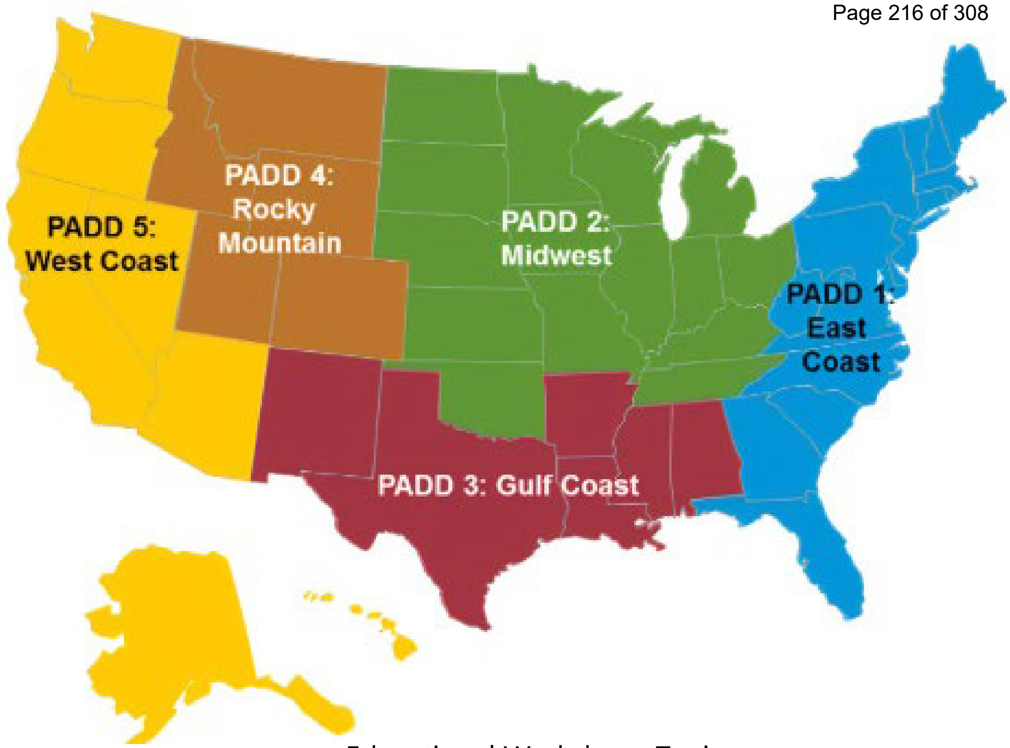
The team is executing on the Gulf Coast regional case study and integrating emerging research on resiliency, and reliability in understanding the value of gas infrastructure in current and future energy systems. Stakeholders will be provided with research analysis and data tools to understand how to leverage the existing gas infrastructure to reach/address decarbonization goals.

Education and Outreach

The team is publishing short-form papers to provide accessible and digestible content for stakeholders to better understand emerging research topics to do with gas infrastructure. This year's planned pipeline of papers includes 'Underground Gas Storage Potential in the East Coast', 'Resource Considerations for a Decarbonized Natural Gas Industry', and 'Reliability and Resiliency of U.S. Energy Systems – a focus on Natural Gas'.

Strengthening collaborations and partnerships

The team is developing the Gulf Coast regional case study with KeyLogic, a highly specialized energy systems modelling partner, and is continuing to work closely with partner organizations such as NARUC, and other regional gas association groups. RAISE has also convened a regional Gulf Coast external advisory group comprised of partners from ICF, RMI, BEG's Center for Energy Economics, and the Texas Hydrogen Alliance.



Results/Status

RAISE has 25 utility and midstream partners from across the country. RAISE has also convened an Advisory Committee comprised of academic experts and stakeholders from the investment and NGO community that includes JP Morgan Chase, CalSTRS, CATF, Kimmeridge, Bipartisan Policy Center, Rocky Mountain Institute, Environmental Defense Fund, and CERES. The team continues to share research among partners and stakeholders such as technology solution providers, federal and state policymakers, investors, and utility companies.

In 2023, RAISE published its first whitepaper detailing the vision for evolving the United States' natural gas infrastructure towards a net-zero future.

For each major U.S. Region (Gulf Coast, Mountain, Midwest, West Coast – North and South, East Coast – North and South), RAISE will develop a final research report (five in total, starting with the Gulf Coast) covering the regional infrastructure scenarios, outlook, and analysis of repurposing opportunities. This will include descriptions of the resource and feedstock availability, infrastructure buildout or retrofit opportunities, cost estimates and technical considerations for each pathway scenario.

The Gulf Coast Case Study is currently in progress and planned to be published by the end of Q2. The Regional Case Study was defined: PADD 1- East Coast, PADD 2 – Midwest, PADD4 – Rocky Mountain, PADD 5 West Coast and PADD 3 – Gulf Coast. The program continues to work on finalizing content development and workshops.

Educational Workshops Topics:

US Gas and Infrastructure Systems: Current state of energy fuels and pipeline infrastructure. Role of gas systems in current and future energy systems.

Innovation in Infrastructure Maintenance & Monitoring: Operational and maintenance best practices. Technology innovations in infrastructure maintenance and monitoring.

Emissions Life Cycle Analysis: NG, RNG, H2: Production pathways and end-use potential of fuels. Emissions intensity and decarbonization considerations.

Renewable Natural Gas/Hydrogen Integration: Technical considerations for incorporating fuels into existing infrastructure systems. Technical readiness of infrastructure and projects.

RAISE successfully held educational workshops with utility commission and expand workshops to stakeholders in Indiana, Ohio, North Carolina. RAISE also wants to expand to other States (New York, New Jersey, Illinois, Pennsylvania).

RAISE initiatives and papers can be found at raise.gti.energy.

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Mercury Action Limits for RNG Specifications Phase 2

The goal of the project is to execute the test plan developed in Phase 1 by Southwest Research Institute (SwRI) for experimental determination of 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.

Project Description

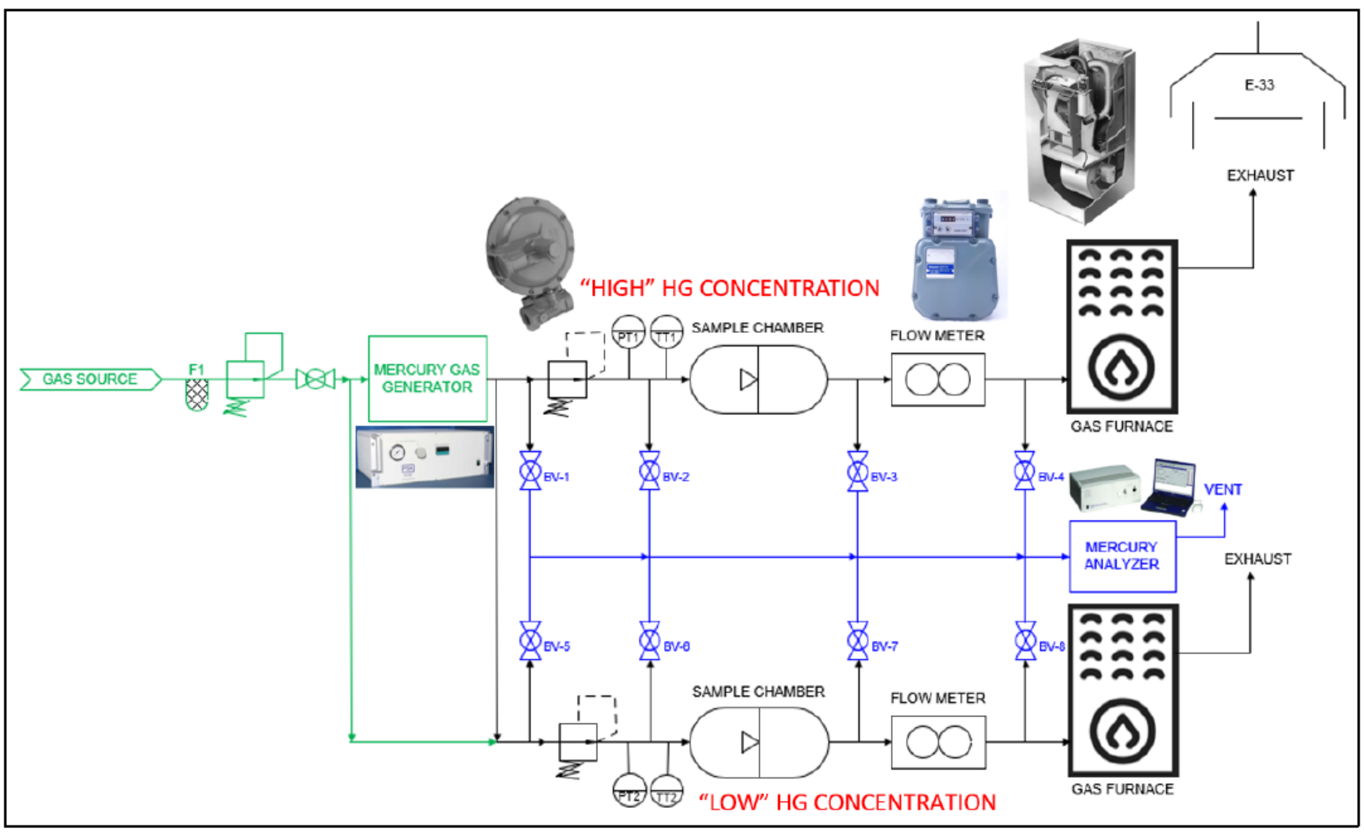
The presence of mercury in gas can promote corrosion. It is unknown at what level this will occur. Upgrading technology for Renewable Natural Gas (RNG) usually successfully removes mercury from the raw biogas. This project seeks to better understand the impact of mercury in production gas and at what concentration the impact would be seen.

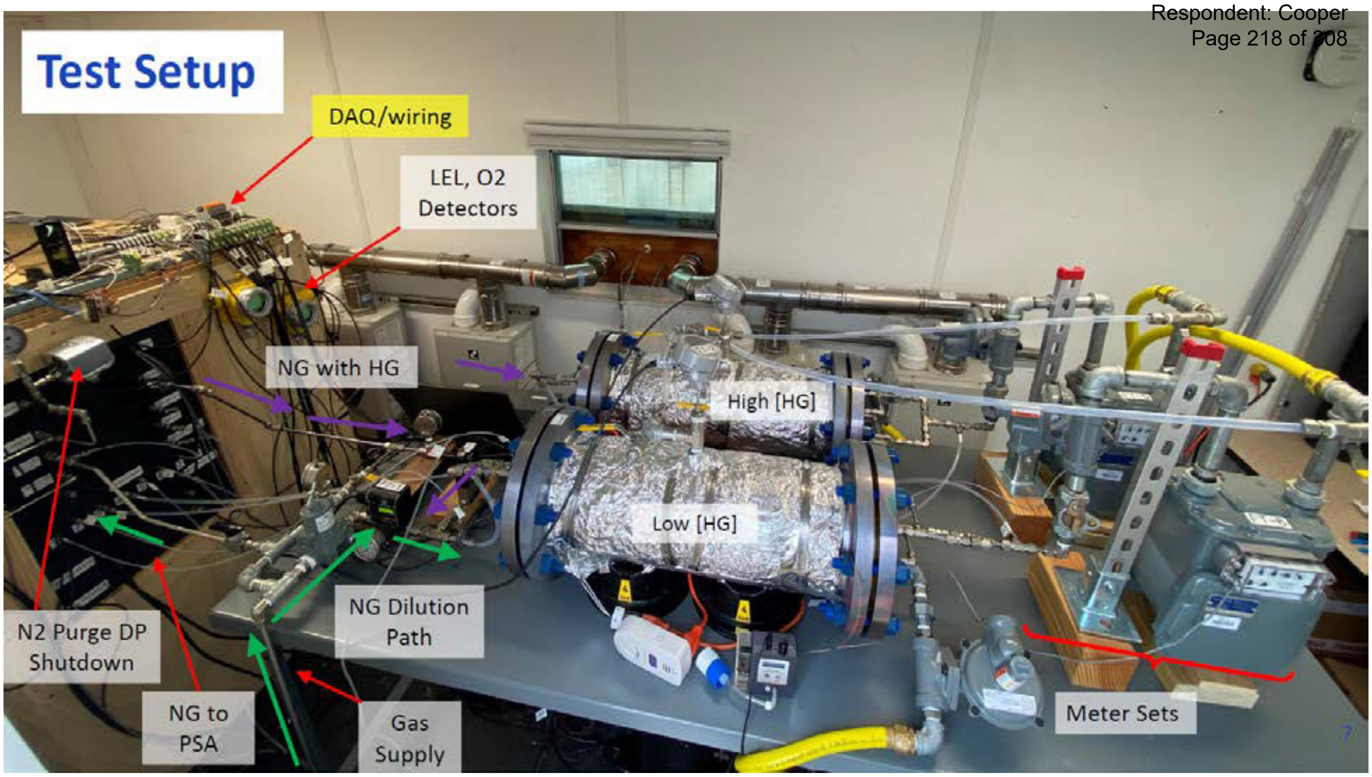
Deliverables

A final report summarizing the test plan developed to test the impact of mercury downstream, and the test results.

Benefits

Renewable Natural Gas (RNG) derived from landfills, WWTPs, dairy farms, food waste processors, and other sources are an important part of the energy decarbonization effort. Anything that limits the introduction of RNG diminishes the decarbonization effort. Developing RNG projects enables capture of emissions that would otherwise enter the atmospheric carbon cycle.





Technical Concept & Approach

The project team will work with SwRI to procure appropriate mercury generator, mercury analyzers, test articles, equipment, and execute the test plan.

The test plan will be executed at 100°F (38°C) and at lower pressure (per end use equipment requirements). Methane or natural gas with mercury concentration of 80 and 800 µg/m3 (trigger level and 10x trigger level) will be used with up to two other levels with higher or lower mercury depending on results. Test articles will include coupons and welded coupons; scratched vs polished with 24 samples for each condition. A gas flow meter and possibly a pressure regulator will be tested to represent distribution equipment while a residential furnace will be used to represent end use equipment. Exposure time for testing will be 2400 hours (100 days) with stoppage after 800 and 1600 hours to characterize materials.

Results/Status

A test system was fully constructed and commissioned. The test plan uses two mercury concentrations of 80 µg/m3 and 800 µg/m3 over a test period of 100 days, with stops at 1/3 and 2/3 of the test period to assess samples and equipment.

Test coupons will consist of 1½" x ¾" coupons (smooth and roughened surface) and 1½" x 1½" welded coupons constructed from 304 and 316 stainless steel, A106 Grade B carbon steel, Aluminum, and Copper. The sample chamber will also contain various parts removed from end use equipment. A meter set assembly will test flow control and pressure regulation.

A tankless, non-condensing water heater will provide gas consumption and additional exposure testing. The hot water heater exhaust system includes an activated carbon-based treatment of the water heater exhaust gas preventing atmospheric emissions of mercury due to the testing.

The first Test Run, including two planned pauses to assess the material and component samples will be completed in Q2 2025.

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Technology for Advanced Natural Gas Detectors

Researchers will evaluate the effectiveness of multi-species and high-sensitivity gas sensors. Sensors from several manufacturers will be tested, including a prototype developed for this project. These sensors will reduce response times to gas 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 in detection 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.

Current RMD (Residential Methane Detectors) reliably detect methane at %LEL levels and alert residents in a timely manner. However, the potential integration of hydrogen into the gas stream and the use of hydrocarbon refrigerants will require additional capabilities. A sensor that can identify type of flammable gas detected helps investigators identify the leak source.

The ability to detect lower gas concentrations, possibly down to 100 ppm, can enable the optimization of sensor deployment. Increased sensitivity may allow fewer devices to cover a larger indoor space.

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 detector based on advanced sensor technology, a reference design and projected costs for a production model based on this sensor technology, and an indoor diffusion study based on Computational Fluid Dynamics (CFD) models to determine the required sensitivity versus distance from the appliance or emission source.

Benefits

Safety is the number one priority for gas distribution systems. Gas leaks, whether they occur inside or outside buildings, require a swift response and investigation by gas utilities. The project's objective is to investigate technology for the next generation of Advanced Fuel Gas Detector (AFGD) devices. It involves exploring sensors capable of detecting multiple gas species and sensors for specific gases at low concentrations. There is increased focus on understanding potential challenges presented by the blending of hydrogen into natural gas systems and increased use of hydrocarbon refrigerants. 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

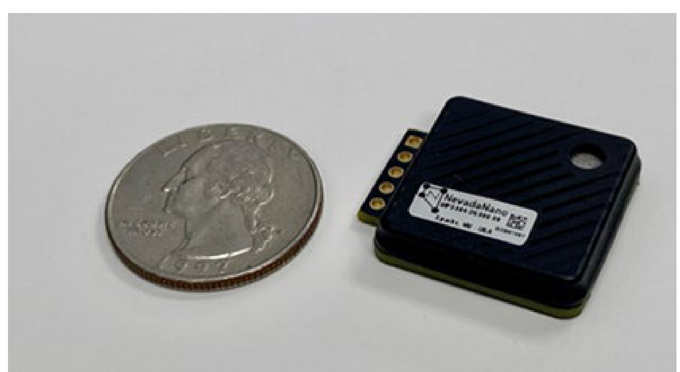
Specific tasks in this project include:

Investigate Multi-Species Sensor Technology

Collaborate with a sensor technology provider to test a multi-species gas detection 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 the 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



Nevada Nanotechnology sensor

DeNova Detect (New Cosmos) natural gas detector

from different manufacturers. Test these detectors for their detection limits and response time. 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 testing sensors from two manufacturers against a series of calibrated test gases. There were some issues with the first round of sensors tested, requiring the manufacturer to replace them. GTI used an in-house Gas Chromatograph with samples of the calibration gas to successfully verify their accuracy. The current devices being tested are performing within the manufacturers' specifications.

Status

The following sensor test series have been completed: hydrogen at 5% and 10% LEL; methane at 10%, 15%, 20%, and 25% LEL. Testing remains to be done with H2/CH4 blends and propane. The project schedule has been extended by 9 months to accommodate this testing.

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OTD Operations Technology Development

Satellite Methane Detection for Distribution Applications

Researchers will evaluate satellite-based detection of methane leaks to determine if distribution operators should consider these tools for monitoring their infrastructure.

Project Description

The objective of this project was to investigate the state of satellite technology for leak surveys and detection by local distribution companies (LDCs). Like many methane detection technologies, satellite-based technology and analytics have been rapidly developed and scaled in the last decade. This technology offers the ability to survey large spatial footprints at a regular cadence with the potential to quickly prioritize leaks that may be hazardous to people and the environment. In this study, the project team investigated these advantages at a distribution-level scale through literature and technology review and by field testing a satellite-based methane detection technology and analysis system on LDC infrastructure.

Deliverables

Deliverables for this project will include a literature review highlighting the state of technology to date, technologies of new market entrants, a test matrix developed to evaluate these technologies along with a robust field campaign, test results, and a final report.

Benefits

Using satellites to enhance leak surveying benefits how LDCs 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 of these products as a useful tool in detecting leaks.

Technical Concept & Approach

Specific tasks in this project include:

Literature Review and Academic Feedback

Work for this task includes reviewing currently published work on evaluating satellites for methane detection, understanding the potential detection improvements of new systems that are proposed or currently coming online, surveying academic/technical experts on the fundamentals of the current state of the technology, determining the crucial variables to satellite-based detection, and defining what elements require further study with respect to applications for distribution systems.

Field-Testing Logistics and Test Matrix Design

The team will work with sponsor companies to understand concerns, questions, and experience with satellite leak detection. Through these conversations the team will identify test opportunities with sponsors and develop a plan for field testing and ground truthing of satellite data. If desired by the sponsors, the team will work with satellite provider(s) in development of the test plan. The team will also develop a statistical/analytical approach for the large amounts of data to be collected.

Go/No Go

Based on the information gathered in the project scoping period and sponsor feedback, a determination will be made on whether a field deployment is warranted.

Field Deployment

The task includes conducting two targeted field deployments to evaluate satellite technology with appropriate follow-up surveys in selected environments. The deployment will include implementing the test matrix and verifying the leak find rate on a subset of leaks.

Single indication shown with plume imagery and wind direction (left) and the clusters created with buffer in GTI map portal (right).

Data Analysis

The amount of data collected will likely be extensive. Data from satellite captures will be evaluated for true positive, true negative, false positive, and false negative 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

The findings from the literature review and interviews indicate that, at this time, satellite-based leak monitoring capabilities require additional development to enhance directed leak surveys in LDC systems.

The project team partnered with one utility sponsor to evaluate the satellite technology through field testing. This field testing included six satellite flyovers coupled with two follow-up field crew investigations to evaluate the leaks indicated by the surveys. Field personnel were blind to the location attribute – satellite indication or control – to maintain consistency in the investigation procedure limiting human factors of finding leaks. Locations were surveyed with industry-standard leak survey tools by experienced GTI Energy personnel and a third-party survey contractor.

The project team found that field crews were practically as likely to find leaks at control locations as satellite-indicated locations. This result supports two important conclusions of this study: (1) technicians using a directed search (i.e., leak investigation at a specific address) can expect to find leaks at approximately 30% of locations in this study area, and (2) that the use of satellite data did not enhance the probability of leak discovery by field crews conducting directed leak surveys. While the project team anticipated finding more leaks based on the leak indications being identified over multiple flyovers, or based on higher flow rates, no relationship between the find rate and these factors was found in this study. The project team identified that sharing existing leak information prior to performing fly over surveys did moderately increase the find rate for existing leaks, but did not improve the probability of discovering new leaks. A final report was shared with OTD members in 2025.

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OTD Operations Technology Development

Methane Detection Technology – Regulation Equivalence Testing

Researchers developed 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 was to develop a protocol to evaluate leak detection technologies on a common benchmark, highlighting functional differences and comparing effectiveness. Equivalence testing of various technologies could provide an understanding of relative detection effectiveness and performance of various technologies. The protocol aimed to be technology agnostic.

Deliverables

The deliverable for this project was 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.

This benchmark allows 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

Specific tasks in this project included:

Review Technical Documentation

Reviewed available comparison studies and test data from previous Advanced Mobile Leak Detection (AMLD) projects.

Protocol Development

Developed a preliminary protocol framework that provides guidelines on testing various technologies and on conducting comparisons between technologies.

Discover AMLD system components (source: Discover Advanced Mobile Leak Detection- Product Brochure)

Alpha Testing of Protocol

Performed benchmarking of protocols on AMLD technologies.

Results/Status

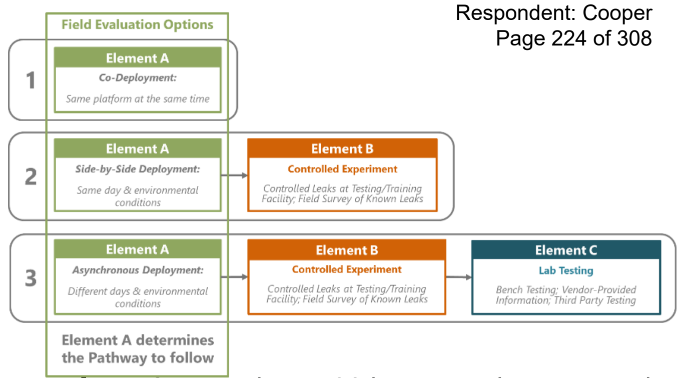
The project team developed a preliminary technology equivalence protocol to evaluate methane detection technologies on common benchmarks for natural gas distribution networks. The protocol is designed to be agnostic to equipment type and focuses on establishing equivalence (equal or better performance) between two or more technologies based on their primary objectives and applications.

The protocol identifies three pathways, each with up to three elements: field evaluation, controlled testing, and laboratory testing.

Field Evaluation would be used to evaluate the performance of two or more instruments in real-world scenarios. This may be done through co-deployment - deploying the instruments on the same platform at the same time, side-by-side deployment - deploying the instruments separately on the same day and under the same environmental conditions, or asynchronous deployment - deploying the systems on different days and in variable environmental conditions.

Controlled Testing would be used to evaluate equivalency with the goal of ensuring adequate performance of the technology and method under variable environmental conditions. This may be done through performing a single blind test under real world conditions with simulated leaks, or performing a single blind test in real world conditions using known leaks in a gas system.

Laboratory Testing would be used to establish the instrument's capabilities with the goal of ensuring the technology capabilities are comparable to the approved technology or relevant performance standard. This can be done through bench testing, using vendor provided information, or through third party testing.



Data from OTD project 7.22.j was used to assess the field evaluation: co-deployment portion of the protocol. This data showed the detection performance of four AMLD technologies on one vehicle. Testing all instruments at one time meant wind speed, available leaks, leak rate, and nearby infrastructure were the same for each device meaning their influence impacted all devices. The relative technology detection performance can then be determined for all devices.

The protocol was presented to sponsors for feedback during development, and the final version provides guidance for comparing technologies while reducing external variable influence. The protocol enables operators to compare devices for specific use cases and could provide substantive data for approving detection technologies within organizations or with regulatory bodies.

The final report on Methane Detection Technology - Regulation Equivalent Testing was completed and released to OTD members in December 2024.

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Operations Technology Development

Renewable Natural Gas Technology Convergence White Paper

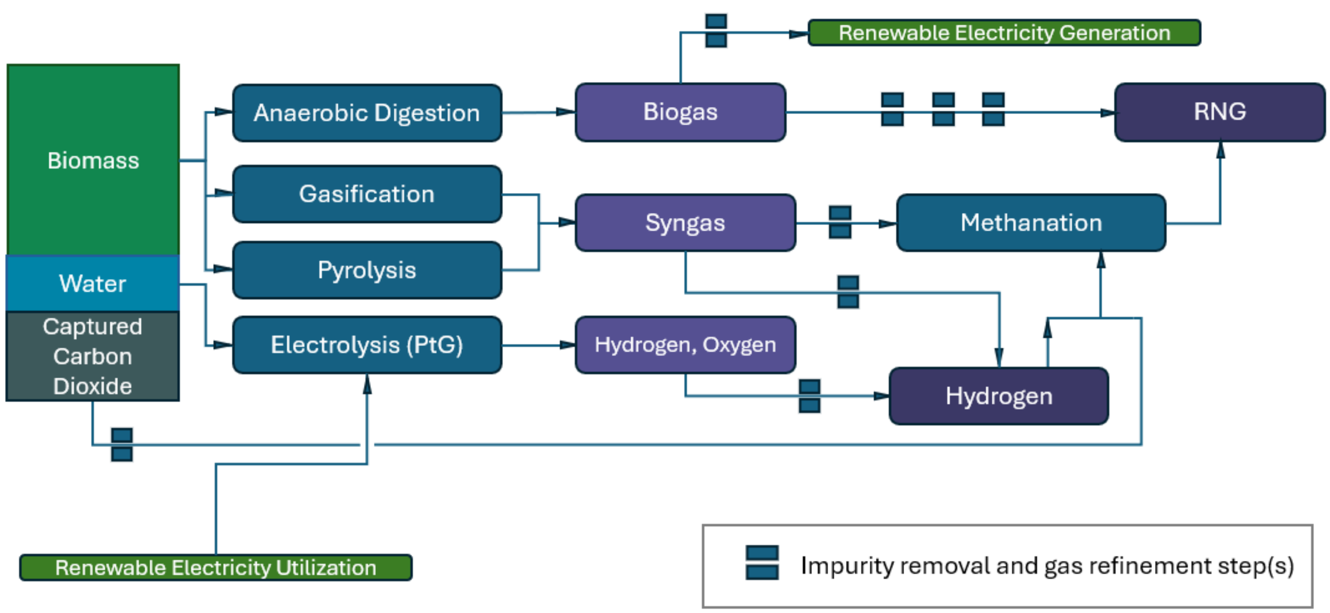
Renewable Natural Gas (RNG) markets in the United States and abroad have sparked interest in developing diverse RNG production pathways with various feedstocks RNG and technology processes. Combining these approaches in new ways could boost RNG production, improve gas quality and byproduct management, and embrace opportunities for deeper decarbonization. Researchers explored how key renewable natural gas (RNG) technology pathways converge to exploit their respective advantages.

Project Description

Though most RNG is produced from biogas, gasification, pyrolysis and Power to Gas (PtG) represent a smaller but growing fraction of RNG production. Technologies such as electrolysis, gasification, and pyrolysis are also of interest in the production of hydrogen and sustainable aviation fuels. Combined technology processes may offer synergies between RNG pathways, address specific local challenges and opportunities, boost RNG production, improve gas quality, and capitalize on emerging value propositions around hydrogen and renewable electricity. Alternative technology retrofits to existing biogas facilities may be an opportunity to increase RNG production or add value in some way.

To understand suitable hybrid retrofits that can incorporate multiple RNG pathway technologies, the strengths, weaknesses, and process requirements of each are considered. Each of the four RNG pathways differ in process efficiencies, production times, product gas quality, process sensitivities, and applicable feedstocks. Although there are major differences between the RNG pathways, this study evaluates suitable applications of each RNG pathway, as well as the current state of hybrid technology design research.

This review discusses where these technologies can be beneficial in existing RNG markets and opportunities for integrating gasification, pyrolysis and PtG with anaerobic digester facilities. Such approaches could help overcome limiting factors that can hin-



*** Excludes alternative fuel production such as SAFs, ammonia*

RNG Technology Pathways

der scaling of RNG production. Combined technology processes may offer synergies to address specific local challenges and opportunities, boost RNG production, improve gas quality, and capitalize on the emerging value propositions around hydrogen and renewable electricity.

Deliverables

A report summarizing the findings from the analysis which outlines the benefits of each pathway was provided.

Benefits

This work directly supported decarbonization efforts by addressing knowledge gaps surrounding different RNG technology pathways and potential benefits of 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 was a need to consider the integration of these technologies in the RNG market.

Technical Concept & Approach

Specific tasks in this project include:

Information Gathering

Leveraged existing knowledge on usage, scalability, and general requirements of the four technology pathways considered. Reviewed research surrounding anaerobic digester retrofits with complementary adjunct technologies, including gasification, pyrolysis, and PtG.

Synthesis of Findings

Outlined applicability of hybrid designs, examining factors that may contribute to technical synergies and project success. Factors such as efficiency, feedstock characteristics, and gas quality are considered.

Results/Status

The team evaluated four RNG pathways: Anaerobic Digestion, Power to Gas, Gasification, and Pyrolysis. Each pathway was evaluated for efficiency, possible integration of renewable energy, required feedstocks, and scalability. Synergies of hybrid designs with multiple technologies may offer advantages arising from regulatory incentives and local factors are explored. There is also potential to merge RNG and hydrogen markets using different pathways, including PtG, gasification, and pyrolysis.

Further research phases could analyze the cost impacts of hybrid RNG designs to determine their economic viability. This further analysis can inform the challenges, benefits, and practical scales of hybrid RNG facilities of various configurations. Understanding gas quality improvements from hybrid systems through chemical analysis of syngas samples could be useful. Overall, hybrid technology designs could enhance RNG production by combining existing anaerobic digesters with complementary adjunct technologies.

This project is complete. The final report on Gas Technology Pathways: Synergies and Unique Value Areas was completed and release to OTD member in September 2024.

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OTD Operations Technology Development

NPRM ALDP Performance Rule 5ppm at 5 feet Evaluation

The objective of this project is to evaluate the New Proposal Rule Making (NPRM) Advance Leak Detection Program (ALDP) by PHMSA 5ppm at 5 feet. The leak survey detection performance criterion will be based on detection performances of current walking survey methods and instruments.

Project Description

PHMSA has proposed that a leak detection performance criterion be established to ensure that the utility industry performs leak surveys to a minimal standard. However, the suggested performance criteria are not within the ability of commercially available leak survey instruments and surveyors. Further, these performance criteria will also be used to audit surveys and to evaluate how utilities are continuing to make improvements in their leak survey program. This project will establish a leak assessment protocol that will enable the evaluation of detectability. Researchers will conduct a long-term field investigation and then establish a statistical basis for a performance criterion.

Deliverables

The deliverables of this project will include collected field data, an audit of field data collected, field data analysis, and final report.

Benefits

This research effort might allow operators the opportunity to meet the intent of proposed federal regulations for leak detection, as the proposed performance criteria are not within the ability of commercially available leak survey instruments and surveyors. Having a performance criterion that is clear, definable, and measurable will facilitate a leak survey detection performance threshold that is achievable and measurable by utilities.

Technical Concept & Approach

Specific tasks in this project include:

Follow PHMSA NPRM ALDP Performance Rulemaking

Follow development and comments of PHMSA NPRM ALDP Performance Rulemaking.

Field test planning

This task will establish a data collection protocol, identify and coordinate utility participation, and define the influencing factors and data collection campaign.

Data mining and analysis of existing leak reports to form a comparative data set

This task will build a database of leak measurements (e.g., %gas, spread); Train participants on the data collection protocol.

Conduct field data collection by LDC leak surveyors

This task will measure and document additional information on found leaks during regular surveys.

Conduct audits of the leak survey and data collection

The project team will conduct both concurrent and post surveys to confirm that field data collection is valid and conduct limited single blind survey on known leaks and collect additional flow measurements.

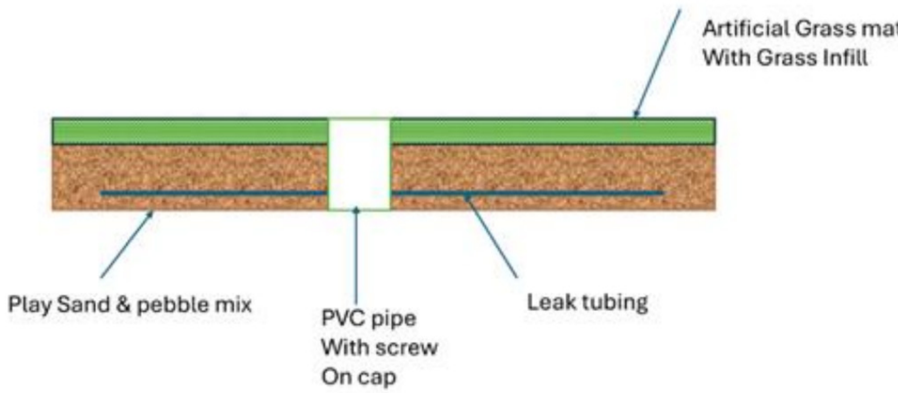
Field data analysis

This task will statistically evaluate leak detection data, establish a minimal detection level (MDL) of 50% probability of detection, establish a readily detectable level (RDL) of 90% probability of detection, and derive a leak survey performance definition and measurement procedure.

Results/Status

The project team held a meeting with LDC sponsors regarding a data collection information request, the team requested information on participating LDC leak survey procedures, past leak survey reports, and the types of data typically collected during routine leak surveys. The data collection form for field testing was finalized and shared with participants. A controlled test plan was developed.

The project team continued to develop a field-testing plan and included a portion of controlled testing to clarify further the relationship between leak rate and measured gas concentration. A controlled study was decided upon to supplement the field data collection. Controlled study plans include the development of a 'sandbox' testing setup in which leaks of varying sizes will be emulated by manipulating the flow rate underneath a gravel substrate. Commonly used pump and laser detection technologies will ultimately provide a better understanding of what concentration readings result in a high probability of detection confidence.



Test Bed Design

Two performance metrics are being investigated based on actual compliance leak surveys. The team is investigating thresholds of a Readily Detectable Leak (RDL), which has a detection rate of 90%, and a Minimally Detectable Leak (MDL), which has only a 50% chance of detection. A field data task is established for LDC to log additional surface expression concentrations and measurements in order to statistically establish what leaks are currently being detected. In addition, the project team is mining data on prior leak reports from LDC. These data are being evaluated along with newly collected field data.

The project team will finalize the testing setup and conduct controlled experiments. The duration of the field data collection is currently scheduled to be completed by the end of Q3 2025.

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OTD Operations Technology Development

Near Field Fixed Monitoring

The objective of this project was to evaluate the use of fixed methane monitors for leak detection to be located near potential high flow locations on above ground equipment.

Project Description

The project aims to evaluate fixed methane sensor options for leak detection. Some gas distribution equipment groups are required to have leaks surveys conducted at a high frequency rate (daily, monthly, etc).

Deliverables

Deliverables for this project included a field test with commercially available fixed point methane sensor and an evaluation of the effective detection rate of the sensors. A public report was developed detailing the team's findings.

Benefits

Fixed methane monitors may aid with early detection of potential high risk and high methane leaks. This evaluation may aid operations in reducing the need for daily monitoring/surveying of such asset classes/equipment. Additionally, incorporating continuous monitoring could allow for fast detection of a major event and reduce overall operations cost and improve emission reductions.

Technical Concept & Approach

Specific tasks in this project included:

Field test

Assisted technology personnel during installation and commissioning.

Feasibility test

Conducted feasibility testing over a period of 2 months; Tracked the rate of indications; Monitored the testing protocol of blind releases.

Field data analysis

Evaluated the effective detection rate of the sensors.

Results

The project team conducted an evaluation for multiple fixed-point sensors. Selected sensors were tested at an underground storage facility. The team worked with sensor providers to procure and install the sensors at the wellhead. The probability of detection for each sensor was calculated by determining, for each test, whether the sensor was able to detect true positives and true negatives., where the types of detection were defined as:

True Positive (TP) - a controlled release and reported detection which were paired.

False Negative (FN) - a controlled release which remained unpaired.

TEST SET-UP IN THE UNDERGROUND STORAGE FACILITY

SENSORS ON TOP OF THE WELL HEAD

False Positive (FP) - a reported detection which remained unpaired.

True Negative (TN) – a correct no reported detection.

Results showed a high variability due to several factors: limited information on the plume reaching the sensors; sensor response due to a high velocity, high pressure release; sensor battery saving duty cycle (length of time on and off); and the gas release strategy and position. Overall, probability of detection for the tested sensors ranged between 9.7 – 38.7 % which shows that continuous monitoring needs further development and evaluation to provide accurate detection on their own.

The team recommends a second phase of testing to further understand and develop the conceptual approach of placing sensors very close to high pressure and high flow leaks. Areas of further testing include a more controlled set of experiments to evaluate sensor performance factors under high flow and high-pressure release conditions as well as extended continuous flow to better measure detection performance over time and weather conditions.

The final report of Near Field Fixed Monitoring was completed and released to OTD members in June 2024.

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OTD Operations Technology Development

Advanced Leak Detection Program (ALDP) Tiered Survey Framework

The objective of this project is to develop a white paper for an initial framework of tiered layers of leak survey methods and their capability. Researchers will identify gaps in knowledge required to formulate and structure the framework.

Project Description

Researchers will develop a white paper to formulate an Advanced Leak Detection Program (ALDP) based on the use of multiple tiers of leak survey methods which includes "advanced leak detection technology." LDCs will need to evaluate and show how their ALDP is performing and how it can be improved by incorporating differing survey methods and technologies. Different survey tiers or methods may have different detection performance and survey frequency limitations.

This project will review the current state of technologies and provide approaches for operators to consider. Next phases of research include developing or leveraging a multi-variable computational model. The intent would be to keep the model simple and adaptable to the specifics of systems or system segments. The project will also evaluate how the framework can be used to measure leak survey detection performance for continuous improvement.

Deliverables

The deliverables of this project will include the development of a framework to formulate the ALDP, a gap analysis, a design analysis, and a final report.

Benefits

Proposed federal regulations will require operators to perform additional inspection of pipelines. This project looks to review methods and help operators understand the technical constraints of technologies, and how to efficiently perform inspection work while meeting regulatory intent.

Technical Concept & Approach

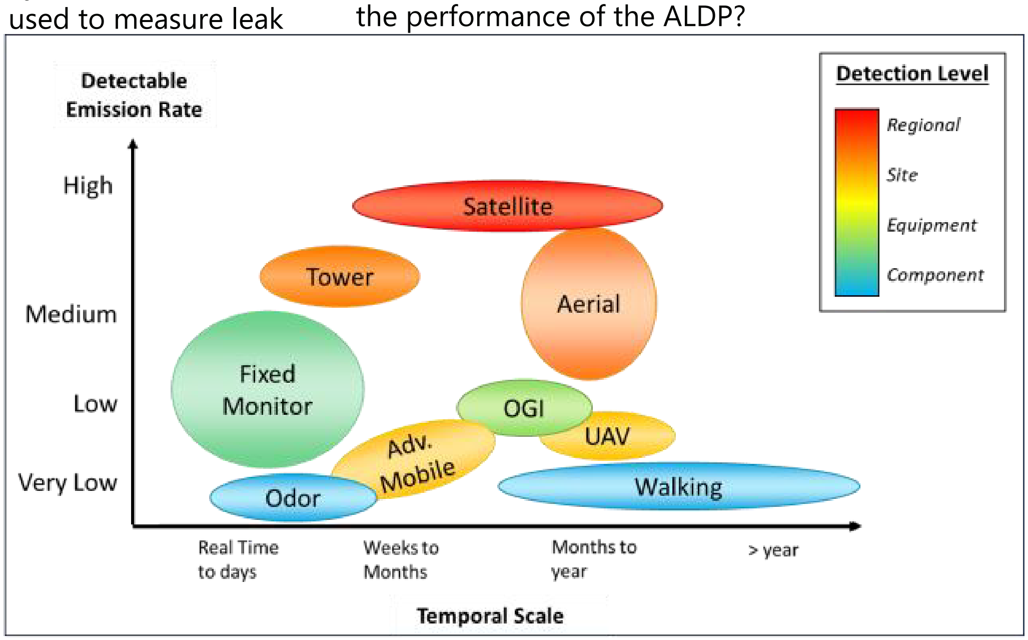
Specific tasks in this project include:

Establish User Group for Ongoing Guidance

The project team will hold regular scheduled meetings (monthly) to gain insight from utility SME on leak detection.

Formulate the requirements of the Framework

This task will address the following questions: What leak detection performance metrics are needed? What statistical approach can be used to assess survey layers? What metrics are needed to evaluate the performance of the ALDP?



Gap analysis

This task will respond the following questions: What information do we know about the survey layers? What information is missing and will have to be derived from further field testing or other sources?

Design analysis of the framework

This task will respond the following questions: What computation methods can be used? How can the framework be adaptable to fit specific system segments? How is the framework to be used by the LDC? How can the framework application be developed and deployed?

Results/Status

The project team developed an initial ALDP concept and defined core elements for understanding the relationship between leak survey system performance and use factors. Leak detection performance and system validation framework requirements were presented to LDCs and SMEs in regularly held user meetings.

A gap analysis of current leak survey methods began by mapping past, present, and proposed projects internal to GTI Energy that may provide knowledge and data applicable to the conceptual ALDP and analysis framework. This effort is ongoing and will continue into the next year to provide clarification on industry knowledge gaps which will need to be addressed in subsequent projects.

The project team will continue to hold user group meetings with the LDC SMEs to further develop and improve the conceptual ALDP framework. The gap analysis of current leak survey methods will continue in relation to the framework design.

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OTD Operations Technology Development

Technology Roadmap for Compressor Station Methane Emissions and Mitigation Scenarios

The objective of this project is to develop a technology roadmap to guide methane emission mitigation/reduction efforts. Design and equipment considerations that can be implemented on new and existing natural gas compressor station facilities will be considered.

Project Description

The project team will develop a technology roadmap of the design and equipment considerations that can be implemented on new and existing natural gas compressor station facilities to drive methane emission mitigation/reduction efforts. The extensive effort will be divided into 3 Focus Areas: gathering and distillation of existing information from on-going development efforts, quantification of potential methane emission reductions through the implementation of new technologies at compressor station facilities, and technology roadmap development.

Deliverables

Deliverables for this project include a comprehensive literature review of technology solutions for detecting, monitoring, and mitigating methane emissions from compressor facilities, a spreadsheet-based model for evaluating potential emission reductions via various pathways, and a multi-layered technology roadmap for compressor facility operators. The findings and recommendations are detailed in a final report.

Benefits

A major challenge associated with U.S. energy systems is protecting people and the environment by advancing the safe transportation of energy and hazardous materials through system infrastructure. In the natural gas supply chain, a critical aspect of addressing that challenge is detecting, quantifying, and mitigating methane emissions.

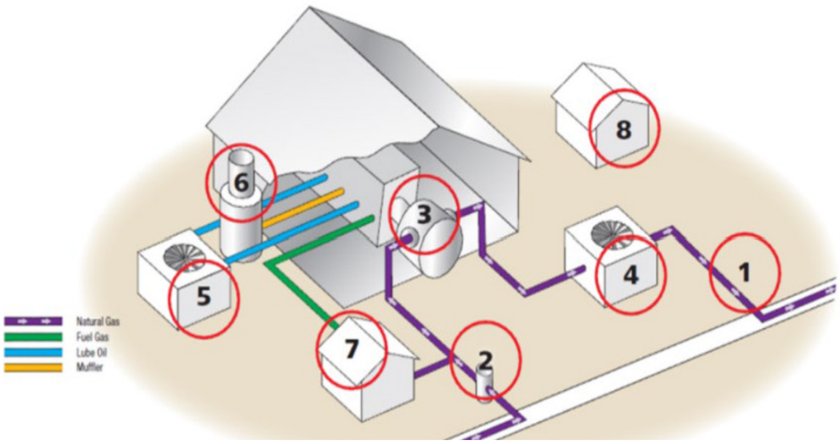
Minimizing methane releases from the entire natural gas supply chain is crucial to reducing impacts to the environment, climate, and safety. Methane is the primary component of natural gas and a potent greenhouse gas (GHG). It is crucial to understand the annual atmospheric methane emissions from the natural gas supply chain so that targeted methods can be deployed across segments to reduce emissions.

Compression of the gas is the largest emission contributor within the gas transmission and distribution sector. Compressors are used along the entire natural gas supply chain to move or store gas across the country. The largest source within compressor stations is from reciprocating engines followed by station venting, engine exhaust, and general fugitive emissions.

Technical Concept & Approach

The project will be divided into three tasks to achieve the goals laid out for the project. The project team will assemble existing peer-reviewed and grey literature on technology solutions that can be used to detect, monitor, and mitigate methane emissions from compressor facilities. The initial literature review will focus on standard operational designs of compressor facilities and problem areas that most enable fugitive emissions. The team will explore available site-level and asset-level emissions estimates and designate relative high emission areas and equipment to prioritize mitigation methods. The second literature review will survey investigation and monitoring technologies to provide operational controls to emission sources. Information gathered from this review will form the basis of the technology roadmap, leading to an ALDP based methodology and procedures framework for compressor stations.

Following the literature review, the project team will use the information gathered on compressor station design to review quantified emissions data. For this task, the team will review strategies for mit-



1. Station Yard Piping / Common Components
2. Filter Separators / Scrubbers
3. Compressor Units
4. Gas Cooling Systems
5. Lube Oil System
6. Mufflers (Blowdown Silencers)
7. Fuel Gas System
8. Backup Generators

igation at multiple levels of operations: equipment, process, and monitoring. Combining equipment repair and replacement strategies with an ALDP, a spreadsheet-based model will be created to evaluate how to estimate potential emission reductions via various pathways.

The project team will organize the information collected in previous tasks into a multi-layered technology roadmap that can be used by compressor facility operators to navigate the potential solutions for mitigating and monitoring/quantifying methane emissions. The focus of the technology roadmap will be in 4 areas – 1) mitigation and station design, 2) emissions monitoring, 3) emissions estimation, and 4) emissions reporting.

Results/Status

Literature resources have been compiled in a database and assembled in tabular outline format. This includes peer reviewed research publication, industry magazine articles, research reports, and industry/conference presentations. The team organized emissions at a compressor station into three categories: emissions vented in normal operations, fugitive emissions from leaks and losses, and emissions associated with incomplete combustion and methane slip. There is a diverse array of technologies available for detecting, quantifying, and monitoring emissions associated with compressor stations.

Preparation of the Interim Report on Emissions Data was completed. The interim report discusses progress including a catalog of equipment and components, emission classification, calculated emissions inventories including GHGRP and GHGI, measurement informed inventories including methane detection and quantification and voluntary LDAR programs, and methane emissions mitigation strategies. Data was compiled from best-available and up-to-date sources and implemented as the baseline in any reduction pathways discussed. Strategies for mitigation were reviewed at multiple levels of operations: equipment, process, and monitoring. Opportunities for improvements such as repurposing vent and flare gas were reviewed and included.

The project team completed methane quantification data assembly and developed a draft user interface to enable streamlined understanding of the pertinent information aggregated, including the current state of quantification in EPA GHGI, and EPA GHGRP, emission attributes specific to equipment types, market available mitigation strategies and associated reduction potentials stated in literature.

A spreadsheet-based model was created to evaluate how to estimate potential emission reductions via various pathways. The spreadsheet provides a comprehensive summary of methane emissions sources at a midstream compressor station. Each emission source is defined in terms of typical emission magnitude, whether allowably quantified with measurement under Subpart W, and available methods of emission reductions. Available emission reduction strategies are first summarized as offering: 1) mitigation via recovery of otherwise fugitive natural gas, 2) mitigation via operational improvements, and 3) mitigation via Upgrades/Repairs/Replacements.

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OTD Operations Technology Development

Differentiating Sewer Gas from Pipeline Gas

The objective of this project was to determine if gases other than ethane could be used to differentiate between sewer gas and pipeline gas in the potential presence of Renewable Natural Gas (RNG).

Project Description

The project investigated whether gases other than ethane could be used to differentiate between sewer gas and pipeline gas. This was necessary because RNG is being introduced into utility pipelines, but it does not contain ethane, making the reliance on ethane detection for leak differentiation invalid. The project entailed a detailed literature search and data mining through the GTI Energy gas trace constituent database to find a compound that was unique to sewer gas.

Deliverables

Deliverables for this project included a literature review to identify a constituent that could be used to differentiate between sewer gas and pipeline gas potentially containing RNG and a summary report with the team's findings.

Benefits

Sewer gas often gets misidentified as company gas, leading to unnecessary labor and economic expenditures locating and fixing leaks that are ultimately discovered to not be due to leaking pipeline gas. Having the ability to differentiate leaks allows prioritization of repair and remediation efforts.

Technical Concept & Approach

Specific tasks in this project included:

A detailed literature search was performed to identify constituents in sewer gas that are not typically found in pipeline gas. The search focused on finding a stable, easily detected constituent that would not be lost while leaking through soil or water.

A selected set of samples identified as sewer gas and collected for leak verification purposes was analyzed for multiple chemical classes such as sulfur, volatile organics, ammonia, and carbon monoxide.

Results/Status

The team researched through the GTI Energy database of past samples of natural gas, raw biogas, and cleaned RNG. It was determined that hydrogen sulfide was the best constituent for differentiating between sewer gas and pipeline gas since sewer gas was likely to contain hydrogen sulfide in high enough amounts to be detected. Lab samples were tested and suspected sewer gas samples showed detectable amounts of hydrogen sulfide along with a high ratio of methane to ethane confirming the sample was sewer gas.

While hydrogen sulfide was identified as a possible constituent to differentiate sewer gas from pipeline gas, there is still more experimental work to be done. The team researched possible detectors that could be able to detect components of both natural gas and sewer gas simultaneously (methane, ethane, and hydrogen sulfide). The identified detectors will need to be further tested.

The project team recommends that OTD move forward with Phase II of the project, which includes laboratory testing of different instruments and detectors to determine if hydrogen sulfide is a feasible constituent for differentiating between sewer gas and pipeline gas.

The final report of Differentiating Sewer Gas from Pipeline Gas was completed and released to OTD members in December 2024.

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OTD Operations Technology Development

Hydrogen Readiness Evaluation Tool

This project will develop a risk evaluation tool to guide an operator through factors they should consider to determine their risk level when introducing hydrogen on the pipeline.

Project Description

The project team will assemble a knowledge base of useful information from past work on hydrogen blending in natural gas distribution and transmission systems. The project team will use this information to develop an interactive evaluation tool with well-defined user inputs which provides an objective assessment of the level of readiness for hydrogen blending and identifies a list of gaps to be addressed to achieve system readiness. The information from this tool will inform integrity, risk, and preventative and mitigative decision making.

Deliverables

The deliverables of this project will include evergreen research findings, identified gaps in the data, and a final report which will outline how to use the evaluation tool developed with this project to assess the readiness of a utility to adopt hydrogen blending in selected pipeline systems.

Benefits

This project will support operators' efforts to introduce hydrogen into their gas systems as a decarbonization method. This project will develop a tool to help operators better document, maintain, organize, and more easily retrieve meaningful information from available research findings to make informed decisions to safely introduce hydrogen into their systems.

Technical Concept & Approach

Specific tasks in this project include:

Analysis of Past Work

An analysis of literature reviews and physical testing reports will be performed of past and current project work to distill the critical information needed and available to develop the assessment tool.

Variable and Use Space Set Up

The project team will set up a variable space for typical natural gas pipeline constructed from various materials. The variables considered will include material properties, dimensions, variables describing the installation and operation of the pipelines, information provided by relevant inspections and engineering reports, and other pertinent information identified in the review.

Selecting and Prioritizing Models

The project team will select and prioritize engineering and risk models utilized for pipeline integrity assessments. The models will serve as the basis of the evaluation tool.

Adapting and Refining Models for Evaluation Tool

The project team will develop the evaluation tool by adapting and refining the selected engineering and risk models to provide a comparative basis for determining expected pipeline performance at various hydrogen blend levels.

Results/Status

The project team presented an overview of the project's intent and approach. A detailed review of past work pertaining to the effects of hydrogen blending on gas transmission and distribution infrastructure was performed. Models for evaluating these effects have been identified, the variable space has been defined, and the team will begin adapting and refining these models to ensure the project objectives are met.

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Service Regulator Relief Venting and Emissions Behavior Investigation

The objective of this project is to review and analyze utilities smart meter data and perform laboratory testing to better understand and determine the possible causes of unusual or irregular service regulator venting behavior.

Project Description

Gas utilities have observed indications in their Advanced Metering Infrastructure (AMI) data that gas service regulators are relieving natural gas at certain times of day without any apparent reason. The cause of this behavior has yet to be determined, but one working theory is that the outlet piping, when sitting in the sun, heats up and causes an expansion of the gas inside the pipe generating a backpressure on the regulator to the point of relief. The theory applies to any differential of temperature on customer owned piping where temperature rises, and pressure rises to the point of gas service regulator relieving.

This project will review the smart meter data, and the project team will work with gas utilities to discuss possible explanations and how they can be tested. One proposed test will be to increase the temperature of the regulator outlet piping and record the internal pressure to determine whether the pressure will rise to a level that causes the regulator to relieve. The regulator's behavior may be caused by multiple variables, so the investigation will examine potential causes separately to draw conclusions.

Deliverables

The deliverables of this project will include a data collection/review of smart meter data, field investigation, a study and the results from laboratory testing, and a final report.

Benefits

With the implementation of smart metering, gas utilities have observed and investigated repeated gas service regulator venting behavior in multiple locations in their service. Utilities discovered this regulator relieving behavior from customer calls and through investigating their smart meter data. An explanation is needed for this regulator behavior to ensure safety. A preventive solution will also assist in the reduction of methane emissions, and reduce cost and impact to resources for responding to service regulator leaks.

Technical Concept & Approach

Specific tasks in this project include:

Smart Meter Data Review & Test Plan Approval

The project team will meet with industry SMEs, engineers, and/or field crews to review smart meter data and field MSA leak investigations. The project team will discuss technical specifics of gas utilities' smart meter data and information from field investigations. The project team will develop a draft laboratory test plan to determine root cause of the venting and have final approval of the test plan by project sponsors.

Implementation of the Laboratory Test Plan

The goal of the test plan will be to determine potential explanations for the regulator relief venting that can be verified through laboratory testing. Using the smart meter data and field investigation information, the team will simulate field conditions and observe regulator relief behavior to attempt to explain the reasons why the regulators are relieving in certain circumstances.

Results/Status

The project team has initiated communication with utilities to organize the sharing of AMI meter data in order to perform data analysis. The aim is to identify field conditions that may cause regulator vent emissions so they can be simulated in a lab environment. Once the team identifies possible reasons for these emissions, a test plan will be developed to evaluate the various hypotheses.

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OTD Operations Technology Development

Leakage Differences between Protected and Unprotected Pipe

The objective of this project is to determine factors that contribute to differences in emissions between cathodic protected and unprotected steel pipes and determine whether any of those factors may need additional evaluation.

Project Description

This project will attempt to generate a clear understanding of factors influencing emissions differences between cathodically protected and unprotected steel, which currently has a higher emission factor. This will involve a review of different pipeline materials, a review of the current state of emissions research on protected and unprotected pipe through literature review, analysis of publicly available data and close collaboration with sponsors to better understand any potential leak trends as a function of pipeline material type, ages, and level/type of cathodic protection.

Deliverables

The deliverables of this project will include a literature review of findings, data collection and data analysis, and a final report. The final report will summarize findings from the literature review, sponsor engagement, leak data trends and recommendations for additional phases of work.

Benefits

Natural gas utilities are required to report their emissions annually, with changes to the distribution and transmission emission factors, there is a need to better understand the underlying factors which can influence the quantification of emissions. A better understanding of these factors could provide a basis for future targeted studies that influence emission factor calculations.

Technical Concept & Approach

Specific tasks in this project include:

Literature Review

Aggregate research findings on the leak propensities of protected and unprotected pipe, and the impacts of cathodic protection integrity.

Data Collection

The project team will request information from the sponsors on geolocated pipeline leaks and associated pipeline materials to understand regional factors such as soil conditions, and potential influence of rural vs. urban settings. The team will also request information on cathodic protection inspection/maintenance practices, specifically, how often cathodic protection is inspected, and practices for inspecting leaking cathodically protected pipes.

Go/No-go Decision

At the completion of the data collection effort, the team will hold an update meeting with sponsors to discuss a go/no-go decision based on the feedback of sponsors.

Information Review and Data Analysis

Data analysis will focus on identifying trends observable with anonymized sponsor datasets and publicly available PHMSA datasets.

Some proposed trends to investigate include determining the average percentage of system inventory for steel categories (both miles of main and number of services), comparing leak rates between operators with above-average steel infrastructure and others, analyzing differences between rural and urban areas regarding leak trends and pipeline materials, identifying survey methods used for leak estimation, and examining how leak grade, material, age, and repair status factor into reported leaks.

The data analysis will also support recommendations in the final report for an additional phase of this project, which can include leak trend validation field studies.

Results

The project team is progressing through the literature review, and data collection. At this stage, the project team has summarized the sources utilized to form the new emission factors for natural gas distribution mains for protected steel pipe. Additionally, the project team has made progress on identifying factors which can affect the efficacy of corrosion mitigation measures for protected pipe (i.e., deficiencies in cathodic protection systems).

The project team has reached out to all sponsors of the project to establish sponsor meetings to discuss company specific practices around cathodic protection system maintenance and data collection practices. Each sponsor was also contacted with a data request outlining attributes of interest, such as leak data identified by pipeline material, location (main/service), pipe installation data, leak class, and survey method. Sponsors were also asked to provide any cathodic protection survey data, such as survey occasion (periodic survey, pipe service/ excavation activity), survey method, survey finding, survey action, pipe installation date. With the sponsors contacted, the project team received data from one sponsor and are awaiting delivery of one additional data package from another sponsor.

Status

The project team will make additional attempts to gain contact from the remaining sponsors to set up meetings and acquire available data. The project team will need to further progress with sponsor engagement to receive necessary data to be able to proceed with the information review and data analysis.

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Comparison of a Correlative Calorimeter to Online GCs

The first objective of this project is to determine how well data from a correlative calorimeter compares to data from a typical on-line gas chromatograph (GC). A secondary objective is to compare the optional CO2 and Hydrogen sensors to the same GC technique.

Project Description

The proposed work is a comparative study to show efficacy of a correlative calorimeter as a less expensive technology alternative for online monitoring of Renewable Natural Gas (RNG) calorific content, CO2, and hydrogen. The results will be compared to a typical on-line gas chromatograph (GC) used by the gas industry which was evaluated in OTD project 7.21.d - Accuracy of H2 Analyzers and Survey Instruments. The reference calorific value will be determined following ASTM D1946 and ASTM D3588.

Deliverables

The deliverable of this project will be a final report summarizing the results of the two evaluation tasks. This information will determine analytical biases for the correlative calorimeter and its associated CO2 and hydrogen sensors in RNG based gas blends.

Benefits

This project evaluates a lower cost alternative to a currently used on-line gas chromatograph device. The alternative option will also provide data on a quicker basis allowing gas control decisions to be made faster.

Technical Concept & Approach

Specific tasks in this project include:

Experimental Setup

This task will involve purchase of the correlative calorimeter. The eleven gases needed for the experimental design will be obtained from gas supply companies.

Performance Testing

This task will evaluate the correlative calorimeter against the most common online GC used by sponsors following test protocols used in OTD project 7.21.d - Accuracy of H2 Analyzers and Survey Instruments. Ten gases will be compared against the base gas for a total of eleven gas runs.

Results/Status

The correlative calorimeter and the various gas test mixtures have been ordered from suppliers. The project team is currently awaiting the arrival of all orders which are expected to arrive in early 2025. Additionally, a location in the lab has been prepared for the calorimeter, and a desktop computer has been installed for the data collection.

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OTD Operations Technology Development

PHMSA COST SHARE Multi compound Green Corrosion Inhibitors for Gas Pipelines

The objectives of this project are to design, synthesize, and screen green corrosion inhibitors from renewable feedstocks; to evaluate the efficacy of the identified inhibitors; and to evaluate inhibitors compatibility with fluid, chemicals, and gas constituents mostly observed in natural gas systems.

Project Description

This project will include extensive laboratory experiments encompassing design and synthesis of green corrosion inhibitors from renewable feedstocks. The team will conduct laboratory testing to evaluate inhibitors effectiveness, validate application methods, and evaluate the inhibitor's compatibility with various gas constituent chemistries as well as with bacterial activities potentially present in gas pipeline operations.

Deliverables

Deliverables from the project include identification of candidate green corrosion inhibitors for pipeline application, data on corrosion inhibitor activity, data on inhibitor compatibility with natural gas components and microbial activity, and final reports with recommended green corrosion inhibitors.

Benefits

Green inhibitors, as an alternative to classical chemical inhibitors, offer great potential to mitigate internal pipeline corrosion effectively while being environmentally friendly and less expensive. Sourced from natural materials like plant extracts, green inhibitors are biodegradable, non-toxic, and demonstrate a reduced environmental impact. From a cost perspective, green corrosion inhibitors are produced from renewable feedstocks and do not have similar handling and disposal challenges as conventional alternatives. Additionally, they provide health and safety advantages by minimizing risks associated with handling, storage, and disposal of hazardous chemicals, making them a superior choice for pipeline corrosion management.

Technical Concept & Approach

Specific tasks in this project include:

Inhibitor design and synthesis

Novel green corrosion inhibitors will be developed from renewable feedstocks such as biowaste and plant extracts.

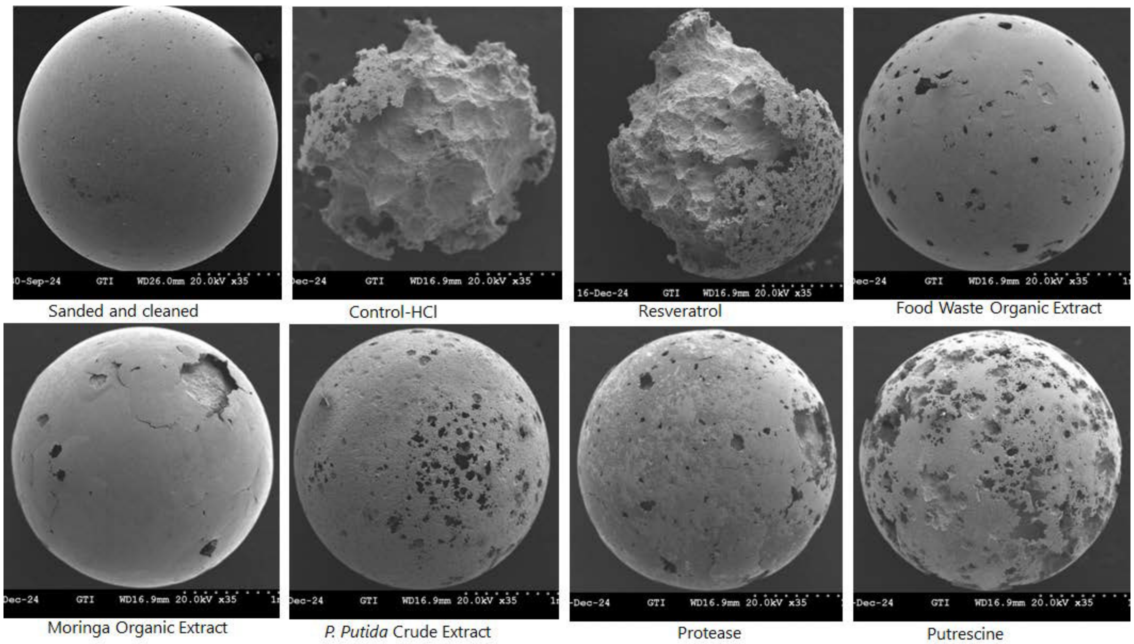
Inhibitor testing under corrosive environment

Different concentrations of the inhibitor solution will be prepared in a suitable solvent by either choosing individual corrosion inhibitor samples or a mixture of selected inhibitors. Corrosion inhibitory activity will be determined by comparing the corrosion rate with controls without the inhibitors. Specimens coated with selected commercial chemical-based corrosion inhibitors will be tested as positive controls along with the green corrosion inhibitor.

Compatibility testing with natural gas components and microbiology

Compatibility of the selected green corrosion inhibitors with compounds commonly observed in gas transporting pipelines or storage infrastructure will be tested in bioreactors. The corrosion inhibitors will be applied to the steel specimens using batch or continuous application. To test compatibility with gaseous constituents, the bioreactor's headspace will be flushed with methane and amended with specific concentration and pressure of CO2 or H2S. The inhibitory activity will be determined by comparing with non-amended and non-treated controls. Compatibility of the selected green corrosion inhibitors with microbial activity will also be evaluated in bioreactors in the presence of biocorrosion-related microorganisms, such as sulfate reducing bacteria (SRB), commonly observed in corroded gas infrastructures.

Feedstocks used for extraction of bioactive compounds for green corrosion inhibitor testing



Morphological changes of beads in 1M HCl in the presence or absence of candidate green corrosion inhibitors after 12 days of incubation.

Results/Status

The team has completed the design of the experimental setup, obtained green corrosion inhibitors, and started experimental screening. A total of 15 natural products were obtained from commercial sources. The products were selected based on the presence of bioactive molecules such as amines, alkaloids, flavonoids, tannins, saponins, or essential oils and also based on their availability for mass production. The selected feedstocks include plant leaves (Moringa oleifera and Eucalyptus sp.), a blend of food waste, microalgae culture (Chlorella sp.), fungi cultures (Phanerochaete chrysosporium and Penicillium chrysogenum), and bacterial culture (Pseudomonas putida) extract.

After a specific growth period (three days for fungi, two days for bacteria, and one week for microalgae), the cultures were harvested. After isolation through centrifugation or chemical extraction with ethyl ether, corrosion inhibitory activities were assessed by the loss of weight of carbon steel (C1018) ball bearings contained in microtiter plates following NACE protocols. The highest weight loss (66 mg) was observed in the presence of resveratrol. The lowest weight loss was observed in the presence of Moringa leaves organic extract (34 mg) followed by putrescine (40 mg).

Beads that showed higher and lower weight losses were selected for SEM imaging and compared with the control, to which the inhibitors were not added. Imaging of the beads indicated aggressive corrosion induced by the HCl solution confirming the weight loss data.

Future research will focus on using different concentration gradients of the selected products at lower concentrations (less than 1,000 ppm) and determining their inhibitory activities in HCl solution. The best candidates for this will be putrescine and Moringa organic extracts, as these showed the lowest weight loss corrosion. The lowest concentrations that showed inhibitory activities will be determined and used for coupon weight loss and electrochemical testing in brine solution that mimic the natural gas fluid constituents.

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OTD
Operations
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Development

Hydrogen Monitoring Solutions

The objective of this project is to review monitoring solutions for 100% hydrogen distribution over the 'last mile' between a production plant and a consumer e.g., at an industrial or fueling station. The project will aim to assess various application types including internal pipe measurement, continuous monitoring, point sensor, etc.

Project Description

This project will include a literature review of existing hydrogen sensing and monitoring methods, along with a market review of vendors and technological applications currently available or in development.Some of the advanced solutions for hydrogen monitoring that have already been identified and will require further investigation include distributed acoustic sensing, advanced pressure monitoring systems, continuously monitoring fixed sensors, and optical detection systems to name a few. Next, the project team will hold discussions with sponsors on any pending needs regarding their existing or future efforts for hydrogen monitoring, and the state of their existing or maturing projects. Where possible, the project team will conduct vendor outreach on the application of their advanced monitoring solutions and potential future collaboration in a field study.

Deliverables

Project deliverables include quarterly reports and a final report. The final report will describe existing and emerging hydrogen monitoring solutions, summarizing maturity level, feasibility in different use cases, and prospective costs. The report will provide guidance on possible solutions that LDCs could employ in hydrogen network operations.

Benefits

This project will identify network monitoring solutions that could generate operational savings and maintain safety on future hydrogen networks as utilities look to enhance both their pure hydrogen distribution and blending capabilities.

Technical Concept & Approach

Specific tasks in this project include:

Background & Literature Review

The task includes review of available comparison studies on existing hydrogen monitoring solutions and test data from previous OTD-SMP projects involving hydrogen sensors. The team will conduct a search of the market for off-the-shelf or near-commercial monitoring technologies.

Sponsor & Vendor Discussion

This task will include discussion with sponsors about any pending needs regarding their existing or future efforts for hydrogen monitoring. The team will conduct vendor outreach on the application of their advanced monitoring solutions or future collaboration in a field study, if possible.

Results

The team completed scoping activities, reaching out to sponsors for feedback concerning the use case and potential technologies to review. The sponsors informed project team that they were most interested in monitoring solutions for pure hydrogen applications in a stationary setting.

The literature review has identified more than 20 noteworthy instruments, methodologies, and emerging technologies in the hydrogen detection sphere, covering ultrasonic, acoustic, and electrochemical sensors. The technologies can be categorized as either fixed devices, handheld monitoring devices, network solutions that can integrate multiple technologies, or emerging methodologies addressed in academic research.

Status

The literature review task is still ongoing and will lead into the next task where members of the project team will reach out to individual vendors whose technologies have been identified as being of interest to OTD utilities.

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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.

T&T – Component Counterfeit Detection, Two Way Product Communication Using GS1 Standards

Researchers built 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 in complexity, verifying the authenticity of products and their supporting documentation has become more challenging. 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 was to develop processes to screen natural gas piping system components for counterfeits. This included 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 included 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 ensure authenticity and supports tracking and traceability to be able to detect counterfeit components prior to a product's 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 included:

Develop System Use Cases

Designed 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

Developed process software to call existing scanning software to sample components during a receiving inspection process, preinstallation process, or mapping process prior to backfill. Developed 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 Prototype System for Demonstration

Used real components to simulate and test the processes created and designed in previous tasks and verified 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.

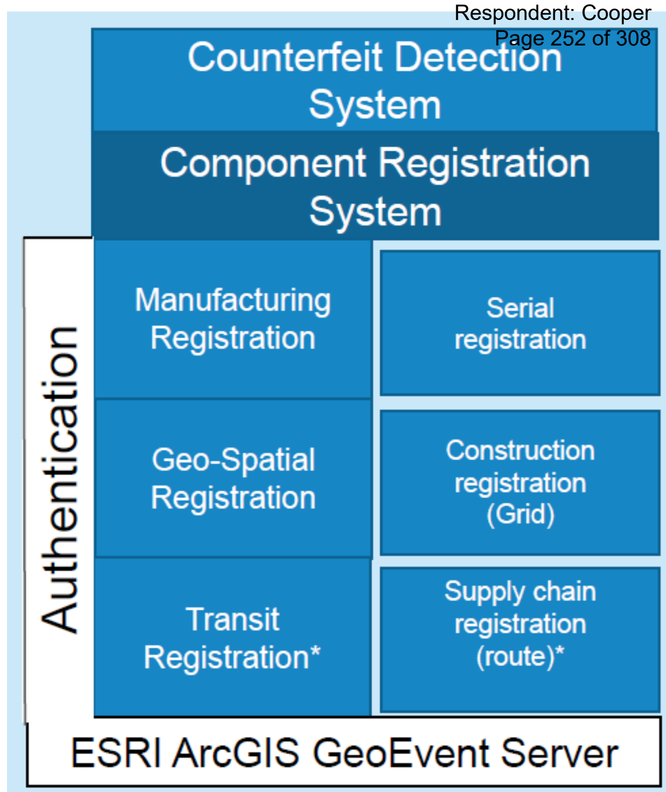
Results/Status

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 GIS-based 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 and half years using Scan-Master 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 store 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 a user interface design based around the concept of a data collection project (storing all scanned records and identifying them under a named project).

The team developed a proof-of-concept that can screen components to be used in construction for several properties using a barcode, assisting utilities in identification of possible counterfeit products. The communications process is simple, fast, and can be tailored to deliver all the track and traceability information contained in the barcode, additional text comments are also supported for transmission to the manufacturer. With the development of this capability, it's reasonable to build and utilize this same communication channel to deliver the identity of equipment purchased by different customers to the manufacturer to assist the manufacturer in contacting the customers for recall of non-conforming materials.



The system can be enhanced to screen for additional counterfeiting methods. The team built the system to look only at manufacturer registration and multiple instances of the same components. It should be possible to extend this concept of data collection for counterfeiting by implementing a chain of custody model with small enhancements in the new proof of concept model. The computational and data storage demands for a commercial implementation are formidable, but well within the limits of modern data processing architectures. Both processes in the system, communications, and counterfeit detection would be delivered as a service by a service provider. Utilities would expect to use a service to implement these types of systems.

The final report on T&T – Component Counterfeit Detection, Two Way Product Communication Using GS1 Standards was completed and released to OTD members in February 2024.

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OTD Operations Technology Development

Corrosion Testing (Longterm Viability) Laser Engraved Barcode

Researchers will develop an estimated life of a direct part mark barcode by correlating barcode verifier readings from barcode samples exposed to weathering conditions.

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.

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, a final report with calculations projecting barcode life cycle estimates, and 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. The project team 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

Specific tasks in this project include:

Manufacture 50-60 Test samples for testing

Purchase of materials and labor to manufacture 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 weathered sample set.

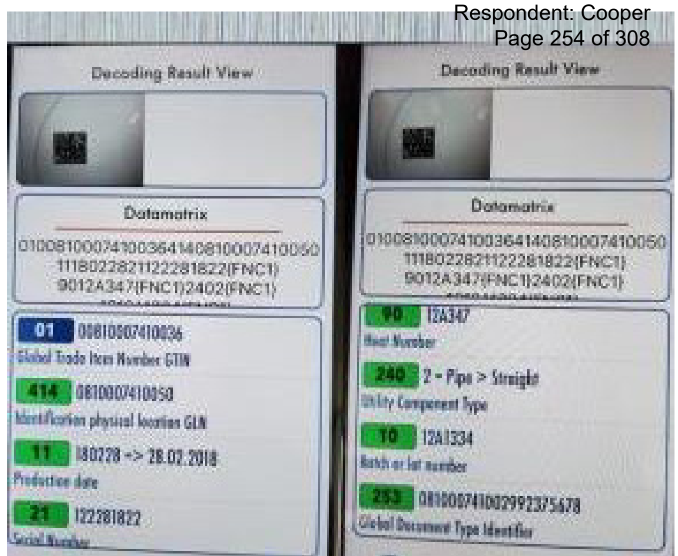
Fifty hours of salt spray. Untreated control barcode on right

Results/Status

The project team 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).

The team also selected a verifier to purchase. 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..

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.



Quality control, checking data for GS1 specification compliance Phase 2

After reconsidering the method of sample identification, a second group of samples was ordered with the identification information encoded in the sample barcode. Each new test barcode sample would have a unique serial number encoded to identify each sample.

All barcode samples for the weathering and corrosion testing were manufactured. Barcode verification software was installed and updated to export per Specification ISO 15415:2011. Verification results for all sixty test samples for corrosion and weathering tests were completed. Testing the first set of samples will occur within the first several weeks of January 2025.

The project team will continue testing. The team will expose barcode test samples to salt fog testing in accordance with ASTM B117. Pending successful resistance to degradation of the samples from this test, the project team will subject additional samples to weathering exposure per ASTM D7869-17 Xenon Arc Exposure Test with Enhanced Light and Water Exposure for Transportation Coatings. This testing will not proceed if the salt fog test proves to challenge the barcode sample's integrity.

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Automations for Tracking and Traceability

Researchers continued 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 was 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 was alternative data collection methods (i.e., drones, cell phones, tablets) while continuing to collect data for training an object detection model. As this model grew, it was tested for its ability to identify and extract natural gas components from field-collected imagery and move the extractions into GIS. This automated process provides the users with a digital twin record of the open trench and allows data to be collected safely and efficiently with very little human intervention and reduced chance of error.

Deliverables

The main project deliverables were: 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 were derived from the computer's ability to identify nat-

Electronic Pushcart with LuxModus Scanner

Digital image of a scanned pipe.

ural gas components and convert them to usable GIS features. 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 tasks in this project included:

Hardware and Software Review

The project team researched 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 also purchased a subset of new devices based on their research, and documented the benefits and considerations for operators to review prior to selecting these devices.

Object Detection Model Training

The project team received images from participating sponsors and began to label images for object detection. Existing models were re-trained based on newly labeled images and tested for accuracy of prediction. The team created a document cataloging image collections for each natural gas component being trained and tested.

Technology Implementation & Testing

The project team collected data via selected devices and stored it in a centralized location. Images were run through the object detection model in a desktop environment and detected assets were reviewed. Images were reviewed for positional accuracy by comparing detection location to the existing location determined with a high accuracy GNSS receiver. The model was also migrated to a cloud environment and functionality of passing collected images to this environment for detection was tested.

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 different gas distribution assets in various field installation scenarios and the team completed the data preparation and cleaning of the input data set. These images were labeled and used to build an object detection model to detect different gas components. These images were tagged with a bounding box around the identified feature and used with Esri's Deep Learning libraries in conjunction with the ArcGIS API to train on several hundred images per class that simulate the real-world scenario to improve the overall object detection and accuracy. The team evaluated and tested the model performance using the georeferenced images processed from the scans.

While the detection results of the extracted features proved promising and successful, the false positives need to be removed from the detection results.

The final report on automation for tracking and traceability was completed and released to OTD members in May 2024.

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Project No. 8.21.b.2

High Accuracy Locator Technology Evaluation

Researchers assessed 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 assessed 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 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 set up a standard testing environment to conduct comparative analyses of the technologies.

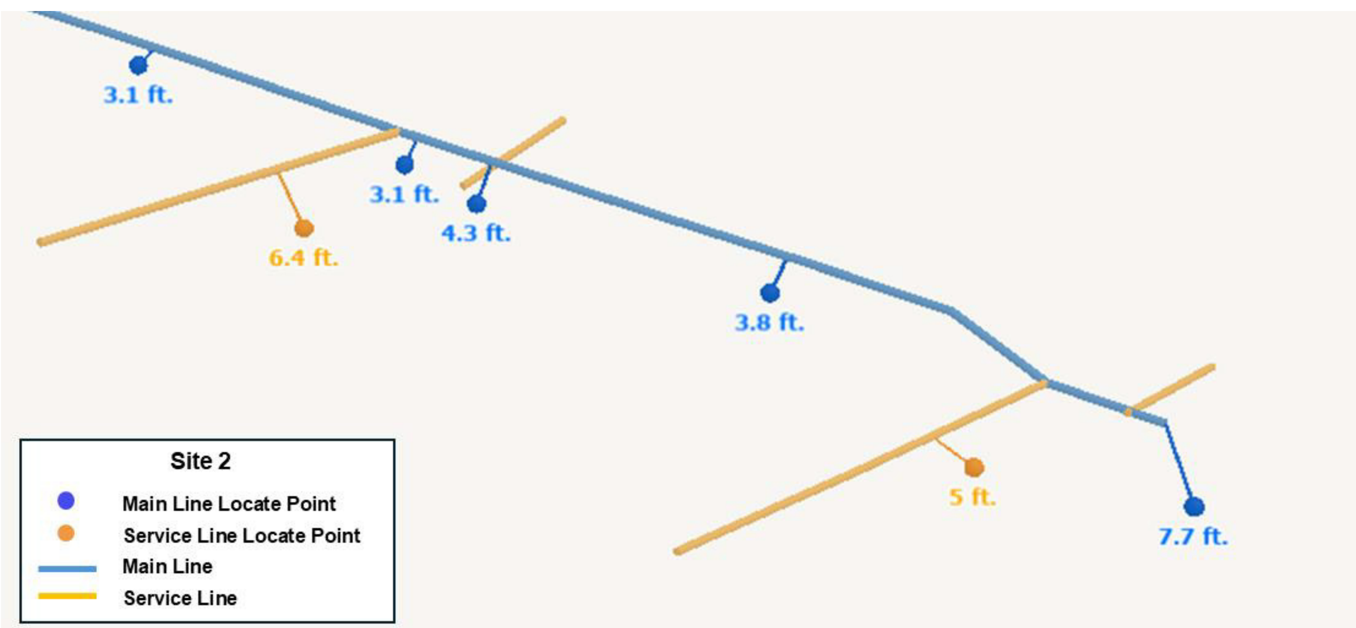
In Phase 1 of this project these technologies were tested in a controlled environment. The testing of these devices occurred at three separate locations with slightly varied backfill materials and some differentiation in the method for establishing a traceable underground signal (i.e., tracer wire and locating tape). For the most part, many of these solutions performed well when locating the underground pipe in a testing environment.

In Phase 2, the team applied these solutions in more realistic field conditions, including utility-congested streets and varied distances from RTK base stations. Testing the ability to maintain connection with base stations under these conditions would be the next step for utility companies interested in understanding the capabilities and limitations of these solutions.

Deliverables

The deliverables for this project included 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.
- A final report and project closeout meeting



Southwest Gas site 2, ArcScene 3D visualizations

GNSS receiver and antenna attached to a locator with a bracket

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.

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

Specific tasks in this project include:

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 technologies for accuracy in locating underground utility infrastructure and for usability.

Results/Status

The findings indicate that digital locating with GNSS offers significant advantages, such as enhanced data accuracy, improved safety, and better integration with GIS and other data systems. Data collected during the pilots proved to be valuable for reference, analysis, and visualization, underscoring the usefulness of digital data in modern utility management. The integration of GNSS with locating data not only facilitates better decision-making but could also foster collaboration among utility companies, ultimately contributing to safer and more efficient construction practices.

Implementing these systems did come with some challenges. Participants reported mixed experiences regarding ease of use, time efficiency, and personnel requirements. The necessity for additional equipment and potential training needs were highlighted as factors that could impact the practicality of adopting these digital solutions in everyday operations.

Moving forward, it is essential to address the identified issues, such as software usability and equipment management, to enhance the viability of digital locating processes. Continued collaboration between the companies developing digital locating products and utility companies will be crucial in refining these technologies and ensuring that they meet the practical needs of the industry.

This project is complete and a final report was issued to OTD members in October 2024.

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OTD Operations Technology Development

Implementing API 5L RP 5MT, "Pipeline Inspection Documents for Material Traceability and Electronic Test Reports "

Researchers developed 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 was 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 supports modern data interchange technology used to transmit data securely across the internet. The data and processes support methods of ensuring 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 included 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

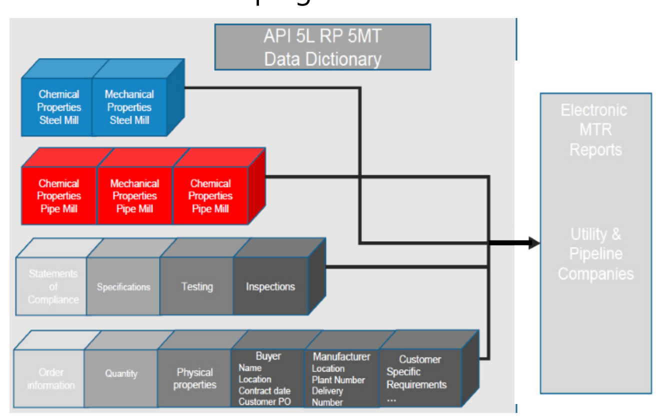
This project will determine the path to delivering a completely digital report for components under specification API 5L by creating the first digital interchange document delineated by RP-5MT. Since RP-5MT is a recommended practice, stock pipe is unlikely to be supplied with a digital MTR without a 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 mechanical and chemical properties for specification compliance. The technology developed by this proposal can minimize the risk of 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 inter-



change option under consideration: Delimited Text Files, Web Services, and 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 of 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 included soliciting 5-10 sample MTR reports from different vendors and checking their data content against the RP-5MT for completeness. The team developed and documented a data model of the interchange option recording each data requirement and its relationship to other parts of the new digital report. The task involved observing the structure of data to determine whether it should be a single entry in the interchange document or require an array of values, as 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 included 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 included the actual data model and accompanying documentation to fully define the entire model to be used to transfer MTR data digitally.

Results/Status

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 operator's pilot was concluded, the team updated its iOS application software to include the digital MTR. A verification system and a two-party digital signature were added to the digital MTR to lock its authenticity and protect it from adulteration.

The team presented the JSON template used in the Dominion of Ohio pilot project to different utilities at the API 2024 Winter Exploration and Production Standards Meeting & API/AGA Joint Committee on Pipeline Welding Practices conference.

This project is complete and a Final Report was issued to OTD members in March of 2024.

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OTD Operations Technology Development

Automation of Digital MTR Processing Pilots

The second phase of this project addresses the manual methods of reviewing material testing reports (MTR) for manufacturing specification compliance and develops a fully digital material test report for market .

Project Description

This phase is the final step to bring fully digital material test reports market. The project team will assist two pipe manufacturers in developing the process code to automatically populate the test results into the new OTD data transfer template. The team will support modifications for any anomalies found in the data transfer template during this project and will review the results of the pipe mills IT work to ensure the digital data complies with API 5L reporting requirements for an MTR and the data dictionary presented in API 5L RP-5MT. The team will provide consulting assistance to the manufacturer in labeling pipe with GS1 standard barcode identification and design and build analytical processes for verification of mechanical and chemical test results in a digital MTR report. This work will be developed on the Apple (IOS) platform. This proposal will develop software to automate this process.

Deliverables

The deliverable of this project is a fully digital material test report, a demonstration of the advantages of the digital MTR from reducing manual processes, and a final report detailing the successes and challenges of the project. The final report will provide a path forward to encourage pipe manufacturing companies to adopt GS1 identification and recommendations on developing additional mobile computing software companies to adopt the techniques and methods developed and used in the two pilot projects defined in this project.

Benefits

The adoption of this technology by pipe manufacturing companies will reduce the time needed to verify each material test report for specification compliance and minimize the potential of mistakenly approving a non-compliant component for use due to human error.

Technical Concept & Approach

Specific tasks in this project include:

Pilot Manufacturer Project Development (MTR)

This task includes design work needed to establish the required infrastructure and introduce the utilities and pipe manufacturers to the digital template used in the Dominion pilot. The project team will review and answer questions about the structure of the digital MTR template and its data requirements, seek clarification, and resolve several key issues discovered in the development of the template. The team will serve in a consulting capacity to assist the pipe manufacturer in converting current reporting programs as a starting step in the development of the needed scripts to populate the Digital template. The project team will provide a review of the output of the manufacturer's scripts and will assist the manufacturer with a database design for storing the digital MTR for issue as requested by the utility.

Pilot GS1 Marking at Manufacturer's Facilities

This task includes the development of printing processes from data derived from the manufacturer's ERP systems to apply GS1 standard identification that is integrated with its production control system. This will include acquisition of the same data used for proprietary identification to tailor it into a GS1 standard identification using GS1 identification standards and GS1 GDSN services for incorporation of product catalog data into the total track and traceability solution.

Pilot Document Integration Sphereon (GTI Verification Storage System)

The team will implement a security layer in the publication of the digital MTR, enabling the distribution of the digital MTR without concern for the authenticity of the digital MTR. Once this task is completed, the digital MTR reports can be distributed and copied, recopied, and verified as genuine. This task is the implementation of W3C specification, Decentralized Identifiers (DIDs) v1.0. This task supports open supply chain trading models for secure documentation and addresses all materials traded where two-party security measures will not protect the digital documents from alteration.

Mobile Analysis

This task includes researching acceptance criteria for chemical and mechanical test results for each type (process of construction) and grade of steel used to manufacture API5L line pipe. The scoping process will identify early on in the project the criteria for manufacturing pipe for a specific customer and will build the acceptance criteria for chemical and mechanical properties for steel specific to the orders placed for the pilot order(s). The process technology will be designed to accommodate additional steel grades and pipe types but will not convert the entire set of criteria from API 5L for other steel grades and pipe construction types covered in API 5L.

Results

The project team has spent time increasing its understanding of the technology used every day to identify products sold both domestically and globally using GS1 standards. This work has become necessary to correct misunderstandings brought up by utility companies when discussing potential pilot programs associated with this project.

This effort is also essential to avoid developing new standards that are incompatible with identifying products traded globally and may be incapable of meeting the ever-growing demand for the integration of digital information across many businesses and country boundaries. This is particularly important for utility and pipeline companies responsible for delivering multiple products and services across distribution and transmissions.

The project team joined the API workgroup addressing machine-readable identification of line pipe. Participating in the API 5L project was not anticipated at the start of this project but is necessary to ensure manufacturers have the necessary information to apply GS1 identification systems. The team has also discussed with several manufacturers to ensure they have the correct information about using GS1 identification systems. The workgroup was developed to add an annex to API RP 5MT for managing machine-readable identification (barcode, RFID, or other digital identification) on API 5L pipe. The first draft was of Identification of Components Used in Energy and Service-related Delivery Systems: Employing Identification Standards and

Standardized System Architectures for Global Track and Traceability. The team also completed the first draft of Industry Group Voluntary Guidelines: GS1 Standards Identification of Utility Components.

The project team continues to provide input to the API work group and, through extended discussions with API, is submitting the Industry Group Voluntary Guidelines document to complement the ANNEX B submittal, providing additional information for manufacturers and utilities to understand how traceability requirements are met across a broad spectrum of industries and providing information to assist utilities in adopting GS1 identification standards. GS1 has fifty years of experience in identifying products produced domestically and globally. GS1 standards and services have been adopted across many industries, and its growth is increasing rapidly.

The project team met with a pipe manufacturer to discuss the requirements for identifying natural gas transmission products using GS1 standards. The team has supplied the pipe manufacturer with a label template and a sample database showing the proper formatting of the data to be included in the barcode.

Status

The project team is still working to secure utility partners to participate in this project. The team continues participating in the API meeting to incorporate the GS1 identification system into API 5L RP-5MT.

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OTD Operations Technology Development

Standardized Utility and Supplier Comanaged Inspection and Test Record Storage

Researchers developed 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 utili-ty and automatically file inbound documents in the correct location.

Project Description

Before this project, there were 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 provided 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 retrieves the documents for review and provides evidence that the properties of the components support the MAOP calculations.

Deliverables

Data collected through the pilot was made available for review by the piloting utility, including a GeoJSON file to upload into their GIS system of record. The team also delivered a final report.

Benefits

This project created 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 also used 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

Specific tasks in this project included:

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.

MTR reports are processed into a (VC) Verifiable Credential ((W3C), 2024). The process stores the VC for access by a mobile iOS application. The documents are made available to a utility by scanning GS1 standard barcodes found on the pipeline component using the iOS application. The utility or pipeline company can scan the barcodes during receiving inspection of the pipe as a screening process for counterfeit product documentation. If the utility does not execute a formal receiving inspection process, they can scan the GS1 barcode during an inspection in the field prior to installation. With its embedded material test report, the VC is delivered to the mobile device at scan time and can be verified for authenticity. The mobile device manages the process of verification, and its interaction with the VC is stored on the central database. For the project, the infrastructure used to store the VC is hosted by GTI on its cloud version of MongoDB.

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 is complete and a Final Report was issued to OTD members in February 2024.

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Pipe Bridge Inspection/Design using LiDAR Drone-based Inspection

Researchers evaluated 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 evaluated the viability of performing aboveground natural gas pipe bridge inspections through the use of Unmanned Aerial Vehicles (UAV). The team assessed 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.

The team collected collect data using drones, analyzed the quality of that data, and produce products that can be used to conduct pipeline maintenance or atmospheric corrosion control. The team will build data collection workflows and identify productivity comparisons to existing methods to help a utility understand the most efficient and repeatable approach to performing necessary inspections.

Deliverables

This project delivered 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 were 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.

Technical Concept & Approach

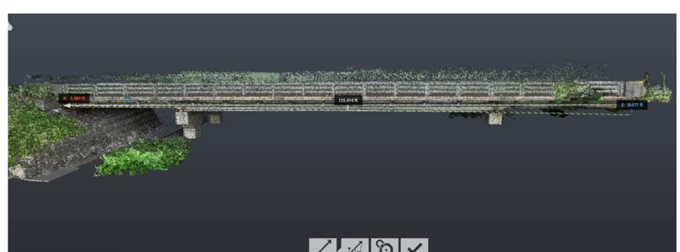
Specific tasks in this project include:

Product Evaluation and Testing

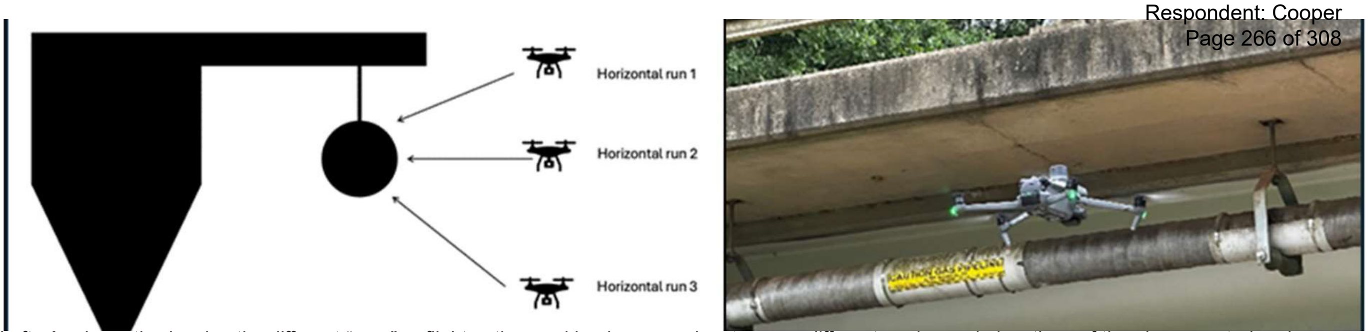
The team identified specific drones and drone solutions that met the needs of pipe bridge inspections,. They evaluated the data products that these drones and drone solutions produced specific to LiDAR, video, and high-resolution imagery as well as the software options to analyze that data. They also developed a workflow for using the appropriate software to derive valuable data for pipe bridge inspections and changes in pipe dimensions

Selection of Drone Technologies

The team worked with three providers for data collection and selected multiple software solutions for evaluation.



An example of measuring a point cloud 3D model of an inspected bridge in AutoDesk Recap software.



Left: A schematic showing the different "runs" or flight paths used by drone vendors to cover different angles and elevations of the pipe mounted under a bridge. Right: A photo of a drone surveying thepipe under the bridge. Figure credit: Left: Aerial Production Services, Right: Southern Cross.

Field Evaluations

The team conducted field evaluations at 3 locations. to test drone data collection on aboveground pipe scans and pipe bridge inspections. The team analyzed the data collected from these scans and documented best practices and workflows.

Results/Status

The team has completed market research and identified drone technologies and selected three service providers to conduct field testing. Each provider had photo, video, and LiDAR capabilities. Field demonstrations were conducted at three locations. The first site was a bridge with a pipe attached under it, the second site was a steep, rocky hillside with a pipeline running along the surface, and the third was a bridge with a pipe attached under it.

Photos and videos for all three vendors were high-resolution and offered clear, close-up imagery of the infrastructure. Photos were typically geotagged which enables integration with other data (e.g., LiDAR) and referencing in map-based interfaces.

Some limitations were identified for the photo and video collection. Low light conditions reduced quality, requiring one provider to return and collect data in better light conditions. Cameras are also frequently mounted on the bottom of the drone, making it difficult to orient the camera upwards to collect images of the bottom of the pipe. One provider did offer upward-facing image collection through their integrated camera-drone platform. Drones which rely on GPS may also be unable to access locations under the bridge, preventing imagery from being collected on all sides of the pipe.

The 3D digital models were classified under two categories: point clouds or mesh. Point clouds are processed LiDAR data that illustrate scanned objects in 3D. This processing integrates the LiDAR scan information with drone position (derived from GNSS/GPS) information to create points and their coordinates that define objects. A mesh is typically a smoothed version of a point cloud. A mesh does not provide as fine geometry as a point cloud, but it appears and feels more realistic. A mesh file is easier to work with as it does not require high-performance computing.

The LiDAR scans and the resulting digital twins offer limited precision in their representation of objects due to the jitter induced by drone movement. Sub-centimeter accuracy is currently not achievable using GPS-dependent drones. LiDAR scans also faced the same limitations as photo and video with lighting and blocked GPS signals being limiting factors.

Numerous software options exist for viewing and analyzing the 3D models. These options enable users to view, rotate, measure, and interact with the models in several ways. Point cloud software can view objects in 3D, convert between coordinate systems, crop, and colorize and classify points. Taking measurements on objects is one of the most useful functionalities, providing real world benefits such as the ability to identify the proximity of potential intrusions (e.g., vegetation, power poles, or trees that could collapse). Mesh software provided similar functionality, although in lower fidelity. Mesh software syncs the 3D model with the collected images, allowing the user to view those (zoomed-in) images in the larger context of the site. Integration of other data sources was often provided as a feature, through the quality varied depending on the data source. Examples include open-source satellite imagery and the addition of digital elevation models.

This project is complete and a final report was issued to OTD members in August 2024.

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OTD Operations Technology Development

Augmented Reality (AR) Technology to Enhance Field Operations

Researchers evaluated the current state of AR technology for its utility to the natural gas industry, focusing on its ability to assist in performing locates, leak surveys, as-builts/planning, construction, providing situational awareness, and capturing 3D scans.

Project Description

This project evaluated 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 provide gas utilities with a better understanding of how leveraging AR technology can help optimize gas-related operations.

- 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:
- 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 were already 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 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 began incorporating functionality to pair with a high accuracy GNSS receiver. This integration helps 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 use cases for the natural gas industry include performing locates, leak surveys, as-builts/planning, construction, situational awareness, and reality capture.

Technical Concept & Approach

Specific tasks in this project include:

Identify Field Operation Activities

Identified 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.

Developed and documented criteria to evaluate the AR technology, including optimizing work efficiency, enhancing work experience, providing increased safety, positive field user experience.

Selection of AR Technologies

Worked with project sponsors to determine which AR technologies they are interested in evaluating. The focus was on the vGIS AR software solution. The chosen AR technology consisted of hardware, software, and supplemental technologies to support the AR systems (GNSS Receivers, Survey Equipment, etc.).

Field Evaluations

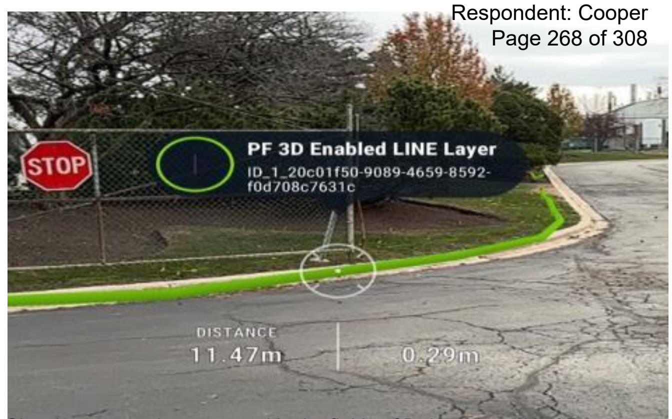
Conducted real-world field evaluations of the selected AR technologies (hardware and software) to validate the full extent of their capabilities and usefulness when conducting the identified field operation activities.

Results/Status

The project team explored the use of AR technology in the gas industry, to enhance field operations and improve safety and efficiency. In this research, the team evaluated the capabilities of the vGIS AR app and other technology solutions to identify workflows that demonstrate how AR technology can be used to en-hance conducting field operations. The research focused on three key use cases: visualizing construction assets, establishing situational awareness, and collecting and visualizing data in AR.

For construction asset visualization the team found that QR/Marker tracking is a viable solution to overlay 3D models of assets onto the real world. Advancements in hardware, such as cameras and LiDAR sensors, continue improving AR applications' performance on mobile devices. Advancements in tracking approaches, such as Simultaneous Localization and Mapping (SLAM) and Visual Positioning Systems (VPS), also show promise in enhancing the accuracy and reliability of AR experiences in the field, though it was not explored in this project.

The team found that spatially annotating sites with visual elements can provide valuable context for



Showing survey data captured in the field as3D data viewed in AR.

field workers. While the project's research was limited to non-immersive mobile (hand-held) devices, the potential for immersive AR experiences using head-mounted displays (HMDs) is worth exploring.

When collecting and visualizing data in AR, the team found that by combining data points and 3D scans, field workers can better their understanding of the site fostering safer and more efficient on-site decisions and operations. Visualizing these digital representations along with spatial annotations in AR can provide field workers with valuable insights and information to improve field operations and safety.

AR technology shows promise as a valuable business resource for its field operators, but there is currently a lack of AR applications that fully support the industry's desired use cases and their ideal workflows. Research and development to create custom AR solutions that meet the specific needs of the gas industry is recommended to help optimize the value of AR technology in the field.

The final report on AR Tech Field Operations was completed and released to OTD members in December 2024.

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OTD Operations Technology Development

Advancing Locating technology with 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 evaluated 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 provided an opportunity for the team to evaluate another platform against the extensive library of locating technologies previously tested at OTD.

Deliverables

This project developed a testing matrix to evaluate the Exodigo technology, which was applied and updated for any potential field demonstration and drafted 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 time-consuming 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.

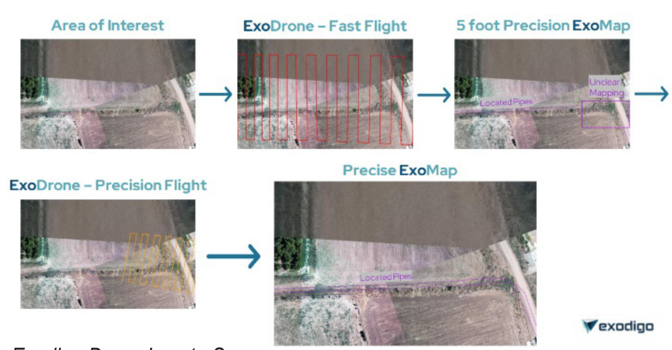
The solution is also available in both aerial and ground-based platforms so that the Exodigo solution is optimized to perform in both rural and urban environments. Exodigo can provide users with a GIS file of the scanned area containing the horizontal (x,y) pipe location, the vertical (z) pipe location (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.

Technical Concept & Approach

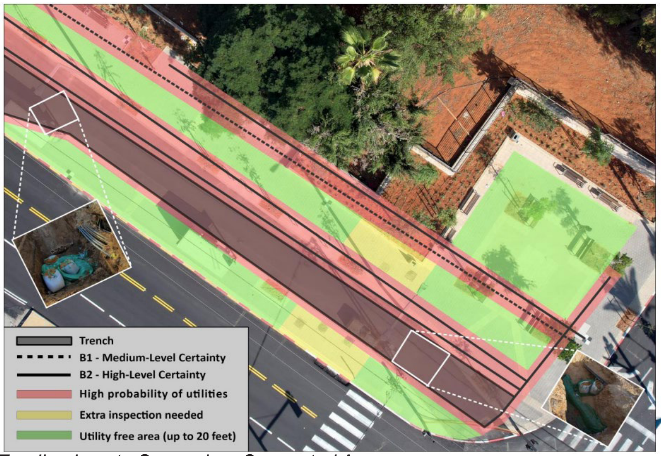
Specific tasks in this project include:

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 performed scans of the pipe farm and provided the team with the results of these locating activities.



Exodigo Drone Locate Survey



Exodigo Locate Survey in a Congested Area

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 developed a testing matrix to evaluate the overall performance of the Exodigo platform to include variables such as duration, material type accuracy, performance in congested areas, and occurrence of missed locates or false positives.

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 allowed the team and Exodigo to collect feedback about the technology and determine its usefulness and feasibility within the gas industry. It also enabled Exodigo to explore other use cases that can serve the gas industry by leveraging different types of sensor technology.

Results/Status

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 compared these scans to the known underground utility locations. Data were compared in the horizontal direction and visualized in the vertical direction. Average accuracy differentials were recorded for the horizontal direction.

The team also analyzed Exodigo testing within the GTI Energy pipe farm and at multiple utilities. Exodigo’s solution proved more capable of detecting underground assets than traditional technologies like electromagnetic locating and ground penetrating radar alone, successfully detecting assets not previously detected by those traditional technologies. Though the technology could not always detect the depth of assets (depending on soil conditions and the size, depth, and material of the assets), the information produced by Exodigo was deemed useful by utility representatives involved in the project, in terms of detection of underground assets.

Exodigo provides scan results in formats useful for construction planning, long-term asset tracking (e.g., in a geographic information system), and analysis (e.g., in spreadsheets). A current drawback is the length of time required for scanning results to be made available to clients, currently on the order of a week or two. Exodigo has stated a goal to reduce that time.

The results and analysis for each test site were presented to the sponsors. The overall assessment is that the solution is accurate and thorough in detecting and locating underground assets and can help avoid the need for exploratory excavation. Areas that can be further improved include the completeness and precision of depth detection and the reduction in turnaround time for results. The project is complete, and a final report has been issued to OTD members.

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Operations Technology Development

3D Monitoring of Terrain Over Pipelines

Researchers evaluated new elevation datasets and developed 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 evaluated 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. This presents a potential challenge 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 benefit from a method that would keep that depth accurate and current. 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 were:

- A Matrix of available Digital Elevation Model (DEM) datasets, including acquisition type, data acquisition costs, and update frequency
- Data workflow documentation, including set-up, data collection and processing, and results
- Documentation on procedures to update 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 paired 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.

Having up to date depth measurements would be valuable to the utility company performing pre-planning and construction activities. Other agencies that may work around the natural gas pipeline infrastructure would benefit equally.

Technical Concept & Approach

Specific tasks in this project included:

Data Acquisition Evaluation

This includes researching available open-source data options available to the public for digital elevation model creation and 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. The project team will also engage in product demonstrations for paid services to review sample data from these types of providers and document these sources and their path to acquisition. Lastly this will include evaluating the viability of acquiring a sample GIS dataset that includes a depth of cover attribute from project sponsors.

Digital Elevation Data Selection

This will include selecting the proper digital elevation dataset(s) based on the various options (i.e., satellite, plane, etc.), purchasing 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, and reviewing acquired data and set up a proper localized data environment for analysis.

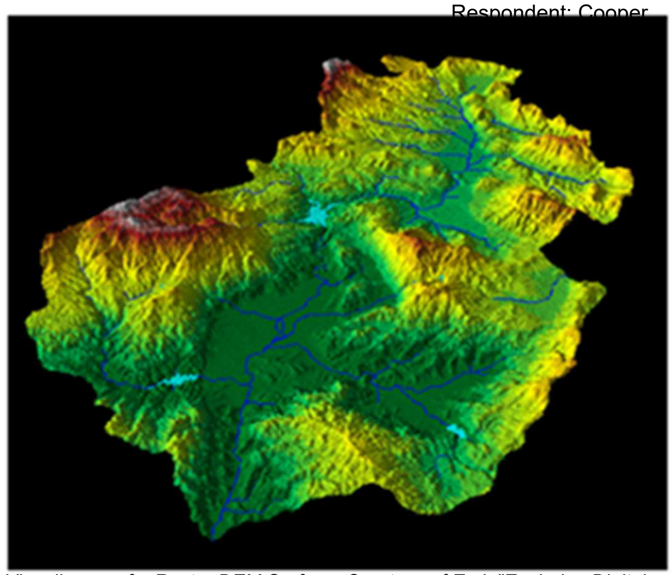
Desktop Data Processing

This involves setting up a localized environment for data processing of acquired digital elevation data, creating digital elevation models based on acquired datasets, and documenting proper data processing steps for all elevation datasets acquired. Additionally, a process will be developed for utilizing newly generated elevation models to update the previously recorded depth of cover within the acquired GIS data. Geoprocessing steps for elevation model creation and depth of cover calculations will also be automated, where possible. Operators will be presented with all the procedures necessary for project sponsors to perform the analysis internally.

Results/Status

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 and 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 also acquired paid satellite data that provides 5-meter satellite-derived DEMs.



Visualization of a Raster DEM Surface, Courtesy of Esri, "Exploring Digital Elevation Models"

To help evaluate which of 5 selected elevation data sources performed best at each project site, the team performed a statistical analysis of the data. Specifically, the mean square error, mean difference (i.e. bias) and standard deviation of the differences between DEM elevations relative to recently measured elevations using high-accuracy, handheld devices were computed. The DEM sources associated with the lowest mean square error provide values closest on average to the located elevations, which implies consistency between the handheld, highly accurate measurements and the DEM, and establishes confidence in the data.

The results of the data collected was submitted to the OTD sponsors. This project is complete and a Final Report was issued to OTD members in September 2024.

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Mapping Inside the Fence with ArcGIS Indoors and Utility Network

Researchers evaluated the feasibility of mapping pipeline facilities "integrity validation 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 the enhancement of records to ensure they are traceable, verifiable, and complete (TVC).

Project Description

This project evaluated the feasibility of mapping pipeline facilities inside the fence that are not traditionally mapped in geographic information systems (GIS) data models. The team evaluated mapping these facilities in two Esri products: Utility Network (UN) and ArcGIS Indoors (Indoors). Additionally, the team performed research to determine what, if any, future regulatory requirements might impact the mapping of facilities inside the fence.

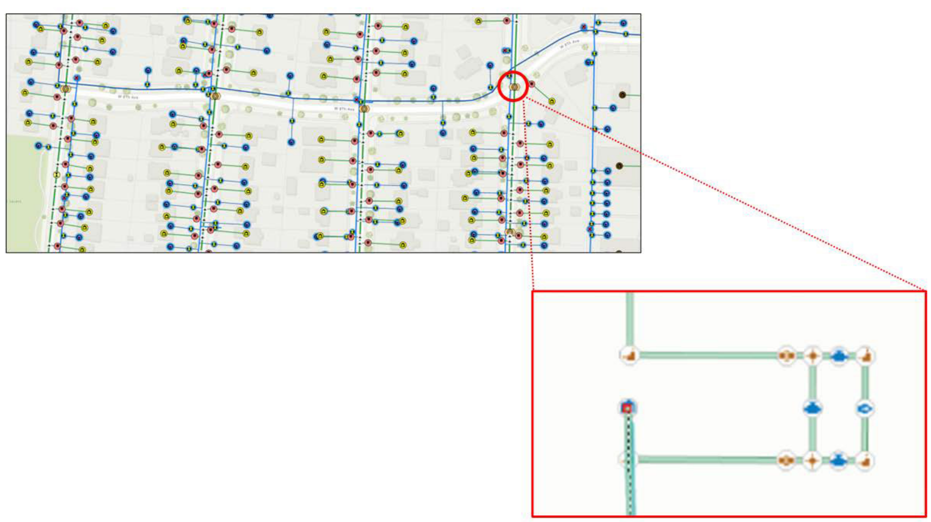
Deliverables

The results of the feasibility analysis were 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 typically mapped as point features with the pipe segments running through them. Complex valve settings are also challenging to represent in a traditional two-dimensional GIS, where features sharing the same vertical plane might have to be stacked atop one another.

Using UN and Indoors can address this challenge by enabling a more detailed representation of the piping than traditional 2-D GIS systems can provide. Additionally, operators can tie CAD documents and 3D models directly into GIS systems using technology such as ArcGIS indoors. With the Pipeline Hazardous Materials Safety Administration's (PHMSA) increasing emphasis on MAOP and materials validation, the pipeline industry also needs to prepare for potential future modifications to data management and reporting requirements within facilities.



An example of a neighborhood gas distribution system. Where traditionally, a riser and valve assembly would be represented with a point (circled red in the top image), Utility Network can capture all features related to the assembly (valves, elbows, bypass piping, etc.) and store them in a GIS system of record.
ArcGIS

Technical Concept & Approach

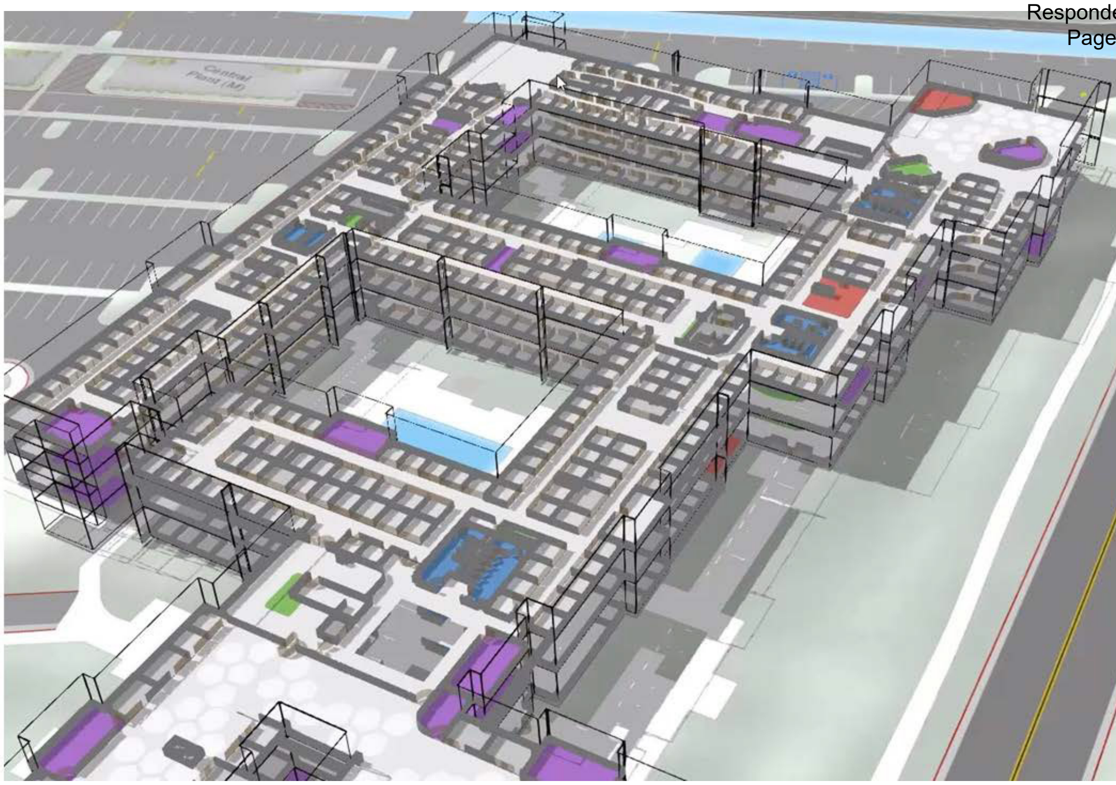
Specific tasks in this project included:

Utility Network Implementation and Data Model Research

The team implemented UN to test the ability to fully model facilities and identified what data models are suited to store facility data, what modifications are needed, and what limitations exist.

Facility Data Collection

The team identified potential facilities for mapping. They collected existing documentation on the facility and any required field data collection. Potential facilities included compressor stations, meter sites, launcher/receivers, or any facility that was traditionally stored as a point feature in a GIS data model.



An example of ArcGIS Indoors, showing a multi-floor structure and spatial distribution of contents.

Modeling and ArcGIS Indoors Evaluation and Testing

The team created a hypothetical piping model for a compressor site to test Indoors. A hypothetical compressor station was first created in UN and then extended to the Indoors software product. The capabilities of Indoors and its ability to model the compressor building structure and hypothetical piping were investigated.

Results

The team determined that the Esri solutions seemed promising and used them for further evaluation. Esri's Utility Network and ArcGIS Indoors can transform a 2D GIS into a system that captures complex assets inside the fence. While the representation of those assets can be schematic, these products offer ideal solutions to operators unable to model a complete system in 3D.

UN and Indoors are designed to capture large datasets and efficiently provide information to the user. They are also designed to work with the Utility and Pipeline Data Model (UPDM) and Pipeline Open Data Standard (PODS) database schemas, which are commonly used across most operator's GIS regardless of the chosen data structure, and they both have evolved to address users' needs, particularly those implementing Utility Networks.

This project sought to demonstrate a pathway forward for operators seeking to capture their entire system of record from end to end, using Esri's well-developed tools. The team tested and confirmed that Esri's Utility Network in particular is an effective solution for distribution and transmission operators alike to incorporate assets inside the fence into a system of record and represent them in a cartographic fashion that is informative to users. By investigating UN and Indoors, the team has provided project sponsors valuable insights through implementation examples and best practice documentation.

The final report on Mapping Inside the Fence with ArcGIS Indoors and Utility Network was completed and released to OTD members in October 2024.

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OTD Operations Technology Development

SSR Correction Service For GNSS Utility Mapping Applications

Researchers developed a mapping service which incorporates satellite SSR correction data via L-Band to simplify field workers ability to obtain accurate captures of buried or above-ground assets.

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 a 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 developed 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 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

Deliverables for this project include:

- 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

L-Band Mapper (cover removed)

Benefits

This project increases the efficiency of the locate processes and improves data quality. Any improvements to data on the location of buried assets will make working with and around those assets more efficient and reduce inadvertent damage to those assets. These benefits also extend to emergency response capabilities which increases safety.

Technical Concept & Approach

Specific tasks in this project include:

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 one or more optional pilots at sponsor locations, including development of a test plan, performing testing, and analyzing the results.

Results/Status

The team developed and deployed for testing an improved mapping device that uses SSR correction data via an L-Band satellite channel. Average precision was 5 inches or better, and the device was able to hold RTK Fixed status for 97% of the time.

The team also upgraded the RF stages and antennas, and redesigned the PCB layout to minimize noise and improve the sensitivity to the L-Band satellite signals, improving performance. The system demonstrated greatly decreased sensitivity to the direction the operator was facing compared to the first stage version, which is important for operator ease of use.

The hardware and firmware architecture were designed to enable relatively seamless integration with new L-Band satellite providers as they become available, allowing the system to switch providers without requiring major redesigns.

The team also conducted initial preparatory investigative work for an "automatic switch" for RTK correction data, which would adaptively choose either L-Band or IP based correction data based on the prevailing conditions. Much work remains to be done in gathering test data, determining heuristics and building a model to control the automatic switching.

A commercial product for the pipeline industry is expected to be released by Q3 2025.

This project is complete and a final report was issued to OTD members in November of 2024.

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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

Specific tasks in this project include:

Coating System working group

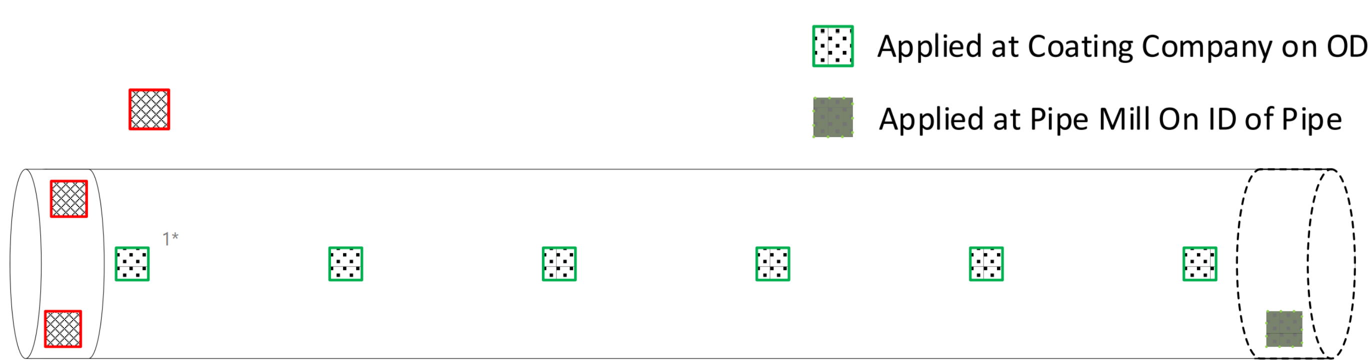
Develop a working group to interact with coating systems manufacturers. This group will consist of coating system manufacturers, end users, coating companies, Pipe manufacturing companies, utilities, and pipeline companies.

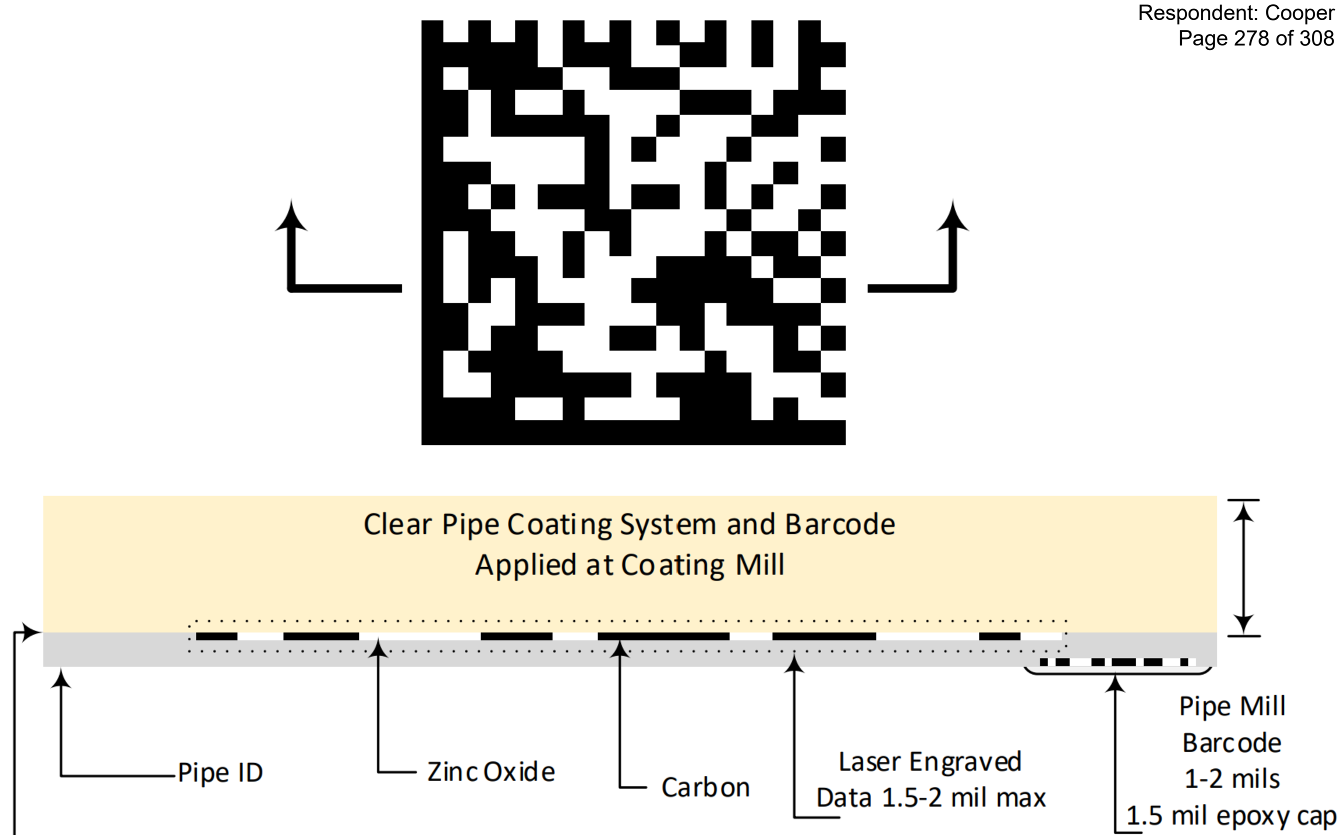
Coating System Development

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.

Initial Design, Mark Pipe, At Weld Preparation, Applied at Pipe Mill

Proposed System to Mark Pipe, Optically Clear Coating





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 project started by looking at several commonly used coating systems that might become clear enough to transfer light if the pigments were removed. The premise was to identify coating systems with optical properties clear enough that would enable the scanning of barcodes engraved into the base metal of the pipe through the clear coating. The project team researched four coating system companies that protect transmission pipe and found no coatings suitable for the initial project scope.

The team started a process to research one of the most widely used coating systems with a significant market share, Fusion Bonded Epoxy (FBE). FBE is applied with a significant thickness that engraving it to no more than a depth of one and one-half mills could provide an opportunity for direct part marking transmission pipe.

The work completed so far in this project has yielded a barcode of one and one-half mills that is easily read by an imaging processing technology running on a cell phone, and the barcode is resilient to damage and not easily counterfeited as is the case with identification using labels.

Status

The team is working to implement a third sample of FBE in brown for engraving to provide a set of laser engraving metrics for the Adhesive Manufacturing FBE coatings that can be used in a production engraving operation suitable for a modern pipe mill. The project team suggests an additional project step in a follow on project to test several clear Abrasion abrasion-resistant overlay (ARO) products for suitability to restore the total thickness of the coating system after the engraving process is complete.

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Developing Routing Solution for Leak Survey

Researchers developed and evaluated potential solutions to improve the efficiency of leak surveys through route optimization.

Project Description

This project developed and evaluated solutions to improve the efficiency of walking and driving leak surveys conducted by utilities by using geospatial data. The team explored current methods used for walking and driving leak surveys and then evaluated existing tools for optimized route planning and developed new capabilities since existing tools did not meet the needs for this task. The team also considered that qualified personnel are required to revisit a known leak location for leak rate testing and optimized 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 were factored in for efficient routing purposes.

The team communicated with industry-based technology providers to determine if routing solutions to efficient leak survey assignment or revisitation routing already exist. A perfect match did not exist, so the team took multiple approaches to developing a solution to meet this need.

Deliverables

Deliverables for this project included a matrix of available route optimization platforms with costs and custom development possibilities, documentation of data workflow including project setup and route optimization processing, procedures for project sponsors to use selected platforms, and a final report.

Benefits

This project has the potential to improve efficiency and reduce the cost associated with leak surveys and revisiting previously identified Class 2 and Class 3 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, having 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

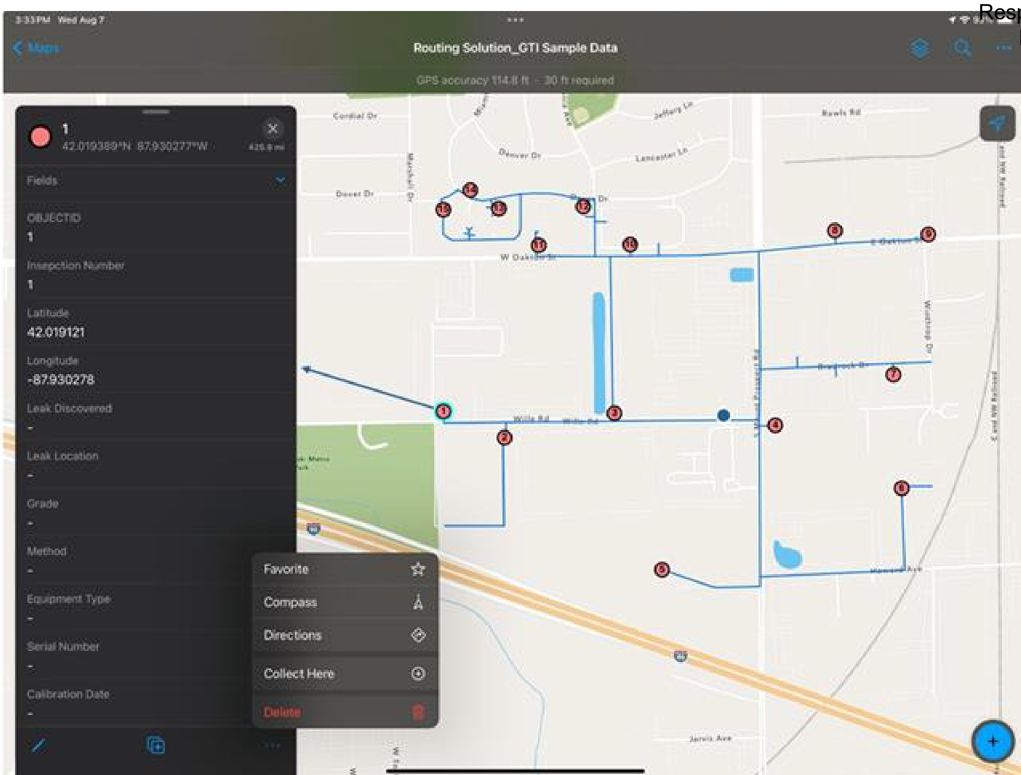
The team consulted with project sponsors to understand current leak survey practices and identify the hardware and software currently being used to perform leak surveys. This task included researching available third-party software and tools for route optimization, as well as evaluating the potential for developing route optimization tools on existing platforms. The team documented these platforms and custom solutions along with their path to acquisition or development, and worked with project sponsors to determine the viability of acquiring sample GIS datasets that include distribution lines and classified leak locations.

Route Optimization Platform Selection

Based on the analysis conducted in the previous task, the team selected route optimization software or add-on components best suited for the application. When existing platforms did not meet requirements, the team documented the functionality needed for custom tool design and modifications to existing tools. This phase involved either purchasing route optimization platforms or creating custom/modified tools to perform the optimization, reviewing acquired GIS data for leak survey analysis, and setting up a proper localized data environment for route optimization testing.

Test Route Optimization Tools

The final task involved finalizing the setup of a localized environment to mimic standard leak survey procedures based on sponsor feedback. The team conducted route optimization tests on sample



Navigating to routing directions from ArcGIS

data and evaluated performance, modifying route optimization settings to find the best fit for the most efficient solution. Results were documented and compared to current leak survey performance times, with all procedures necessary for project sponsors to perform the route optimization analysis internally being thoroughly documented.

Results/Status

The team consulted the stakeholders on the current leak survey practices. 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 and evaluated them against eight success criteria developed through literature review and engagement with LDCs. The first solution involved collaborating with a technology provider to modify their existing routing application to better suit LDC leak survey requirements. The modified mobile application was tested in the field using sample datasets provided by an OTD sponsor and tested near the GTI Energy campus.

The second approach involved using commercially available GIS software to create workflows that route users through assets with GIS data. GTI Energy developed and evaluated mobile field mapping applications as an alternative solution for mobile leak survey routing.

Both solutions met many, but not all, of the success criteria. The first solution excelled in route optimization but had limitations in live tracking and re-routing capabilities. The second solution provided strong GIS integration and data collection capabilities but lacked multi-location route optimization. Each approach showed promise for different aspects of mobile leak survey applications, with specific recommendations for future development phases detailed in the final report.

This project is complete and a Final Report was published for OTD members in August 2024.

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Operations Technology Development

Steel Material Traceability Unique IDs and Smart Tags (Locusview)

The objective of this project is to continue the work to convert the specification for steel material traceability Unique IDs and Smart Tags developed in Phase 1 into an API Recommended Practice.

Project Description

The objective of this project is to convert the specification for steel material traceability Unique IDs and Smart Tags into an API Recommended Practice. LocusView previously submitted an SR3 proposal to API to create a new RP for unique IDs and smart tags. The proposal was rejected but this project will propose a new approach that incorporates the updated specification from the previous project. The results of this project will provide the industry with an API Recommended Practice (RP) that can be referenced when purchasing pipe.

Deliverables

The deliverable for this project includes RP proposal application to API 5L, draft RP, and API RP for Unique IDs and Smart Tags for Steel Material Traceability for Line Pipe.

Benefits

The industry needs a consistent methodology for transferring traceability data from pipe and coating mills into operator's systems of record to ensure compliance with TVC requirements. Smart Tags with industry standard Unique IDs with embedded traceability data will provide a method to automate data transfer and capture of this information.

Technical Concept & Approach

API Recommended Practice

The work in this task will include submitting a proposal for a new RP to the API 5L committee and participating in the voting process at the June 2024 committee meeting. The team will lead a work group to create the RP, which involves soliciting participation for the new work group, converting the specification from the previous project into the API RP format, presenting the specification to the work group, and incorporating work group feedback. Finally, the team will support the balloting and comment resolution process.

Results/Status

The project team drafted the Specification for Steel Material Traceability for Oil and Gas (SCATE). The SCATE Specification was submitted to API Task Group on Line Pipe (TGLP) and went through three rounds of review, comment, and update. The draft final version of the SCATE Specification was submitted to API for balloting as an Annex to API Recommended Practice 5MT.

The project team participated in the API TGLP committee on Feb 3 and 5 to present the draft version of the SCATE Specification.

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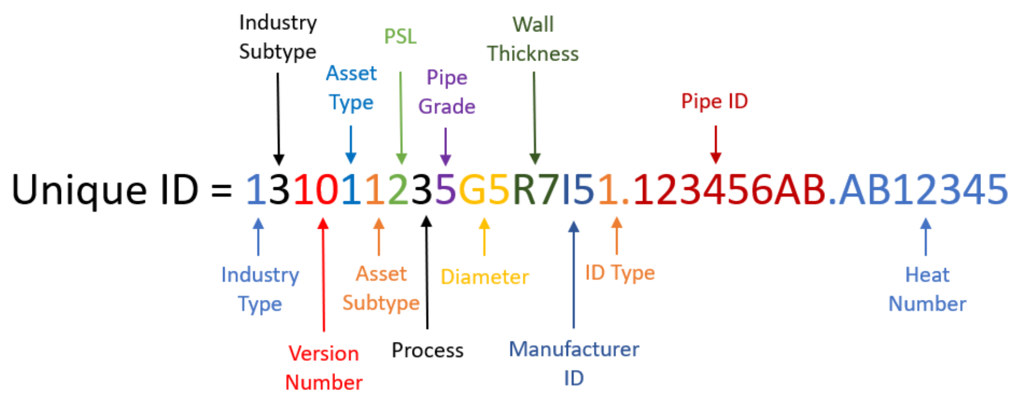


Integrated Methane Monitoring Platform Design

Researchers will develop a System Design Document for an Integrated Methane Monitoring Platform software solution. This will provide better information and support decisions by the scientific community, policy makers, 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 greenhouse gas (GHG) emissions landscape, with methane measurements posing one of the most difficult challenges. Measuring 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.

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 would provide methane emission data to the greater industry, enabling people, organizations, and communities to make informed decisions about the energy transition. This project developed a better understanding of baseline methane emissions data and developed a system design for a software solution to this problem. This project was co-funded by the U.S. Department of Energy.

Deliverables

The main project deliverable will be a system design document.

Benefits

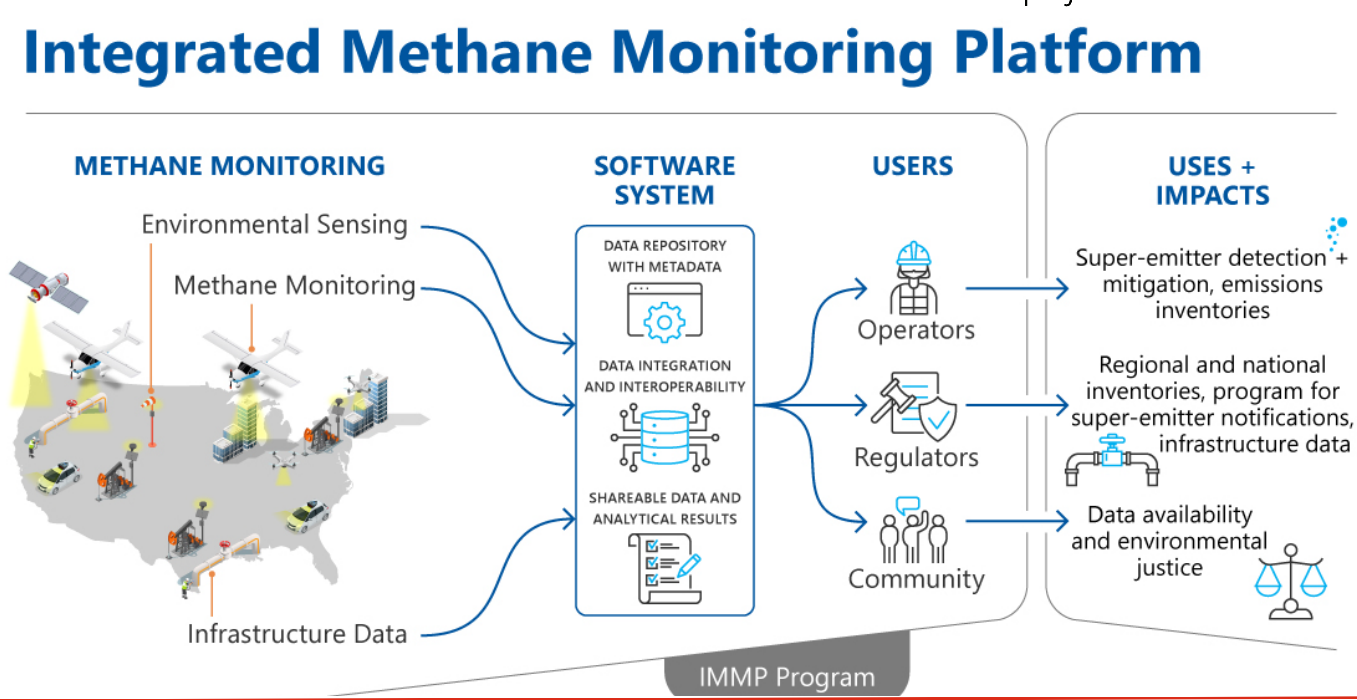
The IMMP will serve the needs of the scientific community, policy makers, and government agencies to better inform decisions around the state of methane emissions and the change in those emissions over time. It would also enable operators to demonstrate progress in reducing emissions.

Technical Concept & Approach

Specific tasks in this project include:

Industry Engagement

The team leveraged learnings from related, large-scale methane emissions projects to inform the



technical panel and the IMMP EDDOP, specifically the Veritas and Project Astra. The team also engaged academics, operators, and technology providers to collect their input.

Public Outreach and Environmental Justice

The team developed a public health, environmental impact, and socio-economic survey which was distributed for anonymous submission.

Technical Advisory Panel

This task included convening 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.

Requirements Gathering

The team gathered all requirements around data formats, methods for aggregating data, uncertainty estimates, platform functional requirements, and other requirements.

System Design

This task included documenting the system, comprised of workflow processes, procedures, and information technology components, resulting in the IMMP EDDOP, delivered as a System Design Document.

Results/Status

The team engaged and considered input from a breadth of potential stakeholders about potential users and applications. These efforts revealed high priority users and use cases that could have substantial impacts. The team also identified the risks and barriers to its effective application and developed strategies for overcoming them. The use cases were used to identify and document the IMMP software system requirements. These requirements drove the software system design.

The team created a deployment and operating plan. This plan identified a phased and programmatic approach to creating an IMMP. The team also used a supply chain agnostic approach, recognizing that emissions reduction challenges exist across the supply chain.

The IMMP envisioned in this project would have capabilities that intersect with those of existing platforms and could even integrate collaboratively with existing software platforms. The IMMP would pull data from systems with publicly available data (e.g., through API connections) and, likewise, push data and analysis to other systems. However, three primary differentiators exist between existing software systems/data platforms and the IMMP envisioned and designed here.

I found the findings, recommendations, and overall reporting (e.g. implementation "plan") to be very thorough, high quality, and exactly what DOE was looking to learn through this effort.

- DOE Program Manager

First, the IMMP software system proposed here is designed to be agile, guided by scientific and technical experts, to immediately address the pressing needs of the industry while being flexible enough to serve new demands from regulators, operators, and communities as they arise.

Second, the software system is one component of a broader IMMP ecosystem that would be supported and sustained through an IMMP program. The IMMP could include monitoring technologies, measurement campaigns, and software. A trusted third party would plan, develop, and operate this platform under an IMMP Program to support stakeholder engagement, outreach, and broad impacts. This program would enable the platform to be adopted by various users and developed by considering multiple stakeholder needs.

Third, the IMMP software system envisioned here is designed to integrate data to enable interoperability. It is not designed for a particular data type or user or tailored to a single service. The importance and requirement of metadata underpins this integration and interoperability. The IMMP would integrate infrastructure and methane emissions monitoring data into a single place and collect the data from multiple sources. This integrated approach enables data accessibility, allowing analytics to be developed and executed more easily, efficiently, and rapidly.

This project is complete. The final report on Integrated Methane Monitoring Platform Design was completed and released to OTD members in December 2024. The U.S. DOE was extremely satisfied with the report. One DOE official stated, "I found the findings, recommendations, and overall reporting (e.g. implementation "plan") to be very thorough, high quality, and exactly what DOE was looking to learn through this effort."

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OTD
Operations
Technology
Development

AI for Field Operations

The objective of phase 2 is to improve Phase I model results by developing models to detect rust on segmented and isolated meter set components, to eliminate background noise, and to leverage Generative AI during model training.

Project Description

Corrosion control and field maintenance for utility assets are essential activities with significant regulatory, safety and cost implications, especially for meter sets. Data collection by field workers is also of paramount importance to monitor and manage risks and increase asset lifespan.

The first phase of AI for Field Operations showed that computer vision can accurately detect and classify rust severity. Phase 2 aims to enhance field data collection, prioritize maintenance for longer asset life and cost savings, and streamline modeling workflows for efficient field data capture.

Additionally, incorporating generative AI into the modeling process has the potential to enhance a wide range of modeling methodologies beyond this specific application. By reducing both the time required for manual training and the number of images needed for model development, generative AI can significantly broaden the context in which models may be trained using synthetic data.

Deliverables

The deliverables for this project include modeling to isolate meter set components, testing generative AI tools to synthesize images of severity-class specific corroded and general meter sets, remodeled and improved model workflow, testing of various workflow and modeling approaches, a strategy for commercialization, and a final report.

Benefits

The benefits of computer vision models to identify rust include improvement of field data collection; informed asset maintenance prioritization and asset lifespan increases; cost savings on part replacements; and improved workflow, accuracy, and efficiency for fieldwork.

Technical Concept & Approach

Specific tasks in this project include:

Meter Set Parts Isolation Modeling

The work in this task will focus on developing models and approaches to isolate and label meter set parts within images of Meter Set Assemblies (MSA's). The team will evaluate various methods

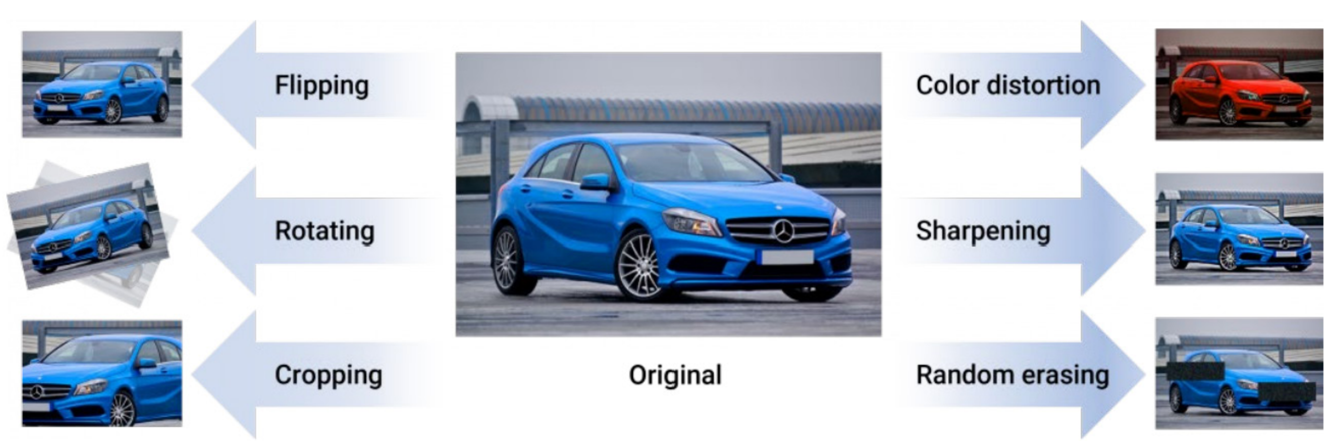

Image Data Augmentation for Computer Vision (2024 Guide) - viso.ai and open-source models to isolate MSA's within images, and then subsequently pursue isolation and labelling of specific components within images of MSA's.

Generative AI for Synthesis

The work in this task will focus on testing Generative AI diffusion models to create a novel, useful dataset of MSA's characterized by distinct (labeled) levels of corrosion, for inclusion in classification and instance segmentation model training.

Computer Vision Models Re-Training + Modelling Workflow Testing

The work in this task will integrate all work completed up until this point, including the modelling output of AI for Field Ops, Phase 1. The team will re-train models completed as part of AI for Field Ops, Phase I, with the supplemental imagery created as part of the Generative AI for Synthesis task. The Team will design and test a workflow for classification and instance segmentation computer vision models with the meter set parts isolation model developed on previous task.

Commercialization and Implementation

The team will create a commercialization plan to deploy MSA models for field usage, both for corrosion detection and other purposes. The project team will conduct market research and consult with interested parties on product access, design, and testing.

Results

The Project team continues to test emerging methods for improving Phase I results to identify corrosion on Meter Set Assemblies (MSA's).

The project team finished testing implementation of the Microsoft Azure Vision AI background removal tool and the Meta Segment Anything Model (SAM). These tools were tested separately for their ability to enhance the precision and efficiency of their image analysis processes.

Segment Anything Model (SAM)

Segment Anything | Meta AI (segment-anything.com)

The Microsoft Azure Vision AI tool accurately identified and separated background elements from primary subjects in images, significantly improving data clarity and usability. This will ideally help alleviate issues encountered in Phase I in which background elements were resulting in false positive identification of rust and corrosion.

The Meta Segment Anything Model provided advanced segmentation capabilities for detailed analysis of image, which enhanced component identification. The positive results imply the viability of a model chain to more efficiently process images for corrosion identification and analysis.

Testing around using generative AI for 2D images for synthetic creation of training images is ongoing and near complete with research confirming the viability of synthetic data methods for training data but raising questions about whether 2D imagery created using generative AI currently satisfies use-case requirements.

Status

Subsequent work will focus on integrating the tools tested into an improved and re-worked version of the Phase I computer vision models.

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OTD Operations Technology Development

Data Driven Investigation of Inspection Intervals

This project's objective is to substantiate the frequency of inspection intervals by analyzing and modeling operator data.

Project Description

Local distribution operators are subject to federal, state, and local regulations requiring the regular inspection of distribution infrastructure. Although these patrols and surveys are paramount to maintaining safety, they are may at times require ground crews to walk hundreds of miles of pipeline and thousands of service lines and meters. New technologies, such as advanced mobile leak detection, have provided solutions to improving overall system monitoring and supplementing these walking surveys. Furthermore, infrastructure characteristics, such as age and material type of pipelines, can be used to explain differences in the rates of leaks and other pipeline failures. These new monitoring technologies and infrastructure knowledge provide a means to use data to inform inspection intervals.

Deliverables

The deliverables for this project include an analysis of operator data to evaluate the best inspection intervals, identification of appropriate safety and risk metrics, a model of those metrics, and a final presentation and report.

Benefits

Operators have limited resources to conduct infrastructure inspections. Inspection intervals that are informed by data have the potential to gain operational efficiencies and have field personnel perform other work..

Technical Concept & Approach

Specific tasks in this project include:

Identification of metrics and data sources

This task will involve working with sponsors to identify the metrics that can be used to substantiate inspection intervals, such as risk, integrity, and safety metrics. After identifying these outcome metrics, the team will work with sponsors to identify data streams that can be used to quantify those metrics and data that can be used to predict or explain those metrics. These data could include the results of past inspections, customer leak reports, leak tickets, failure data, repair data, or other monitoring (e.g., AMLD) results.

Data management and cleaning

This task will involve collecting, storing, and cleaning data for data analysis. After the relevant data have been identified, this task will focus on gathering and securely storing the data. The data will then be merged, cleaned, and otherwise quality controlled to ensure reliable modeling results.

Model development and data analysis

The team will identify and develop appropriate statistical methods that can be used to model the outcomes. This task will involve the execution of the developed models to analyze the data, check modeling assumptions, and generate tables and graphics.

Results

The team reviewed federal and state regulations for leak surveys. The team also met with sponsors to understand company-specific leak survey practices that go beyond the regulatory requirements. The team established a data management plan and developed a SharePoint site for secure data transfer and storage.

The project team has received two datasets and created data dictionaries to confirm understanding of the data fields and enable appropriate interpretation. The team conducted an initial analysis to determine a path forward for achieving the project objectives. However, the analysis has faced several challenges, including incomplete data and misalignment between the two datasets, which have complicated progress toward achieving the objectives.

Status

Efforts to obtain more data are ongoing, and the team anticipates receiving further datasets to complete the analysis, address sponsor questions, and meet project objectives. If data sharing continues to be delayed, the team will identify ways to utilize other data and information sources, such as published literature, to formulate the model.

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Operations Technology Development

Identifying Functional Issues with High Frequency AMI Reads

This project's objective is to analyze high frequency AMI data to develop methods for identifying abnormal gas usage arising from upset conditions, enabling utilities to more quickly respond to potential issues.

Project Description

This project will analyze high frequency AMI meter readings to develop methods to identify anomalies. These anomalies may be due to tampering, theft, equipment failure, leaks, or unusual customer behavior. Using data from high-frequency meter readings and incidents of anomalies, this project will develop and apply statistical techniques for analyzing the data to identify these upset conditions. Mining and analyzing these data can enhance operations by improving safety and billing, assessing equipment health, and reducing theft. This project will also collect learnings from operators with existing AMI analytics programs for identifying customer gas usage anomalies.

Deliverables

The developed approaches will be documented in a final report that will include analysis results, challenges of analysis, and areas of future work. Algorithms and analysis approaches will be available to sponsors via code sharing.

Benefits

Smart meters and high frequency meter readings produce large volumes of data that can improve gas operations by enabling the detection of tampering, theft, failure states, or other anomalies. Identifying these features can save utilities and customers money and improve the safety of local distribution systems.

Technical Concept & Approach

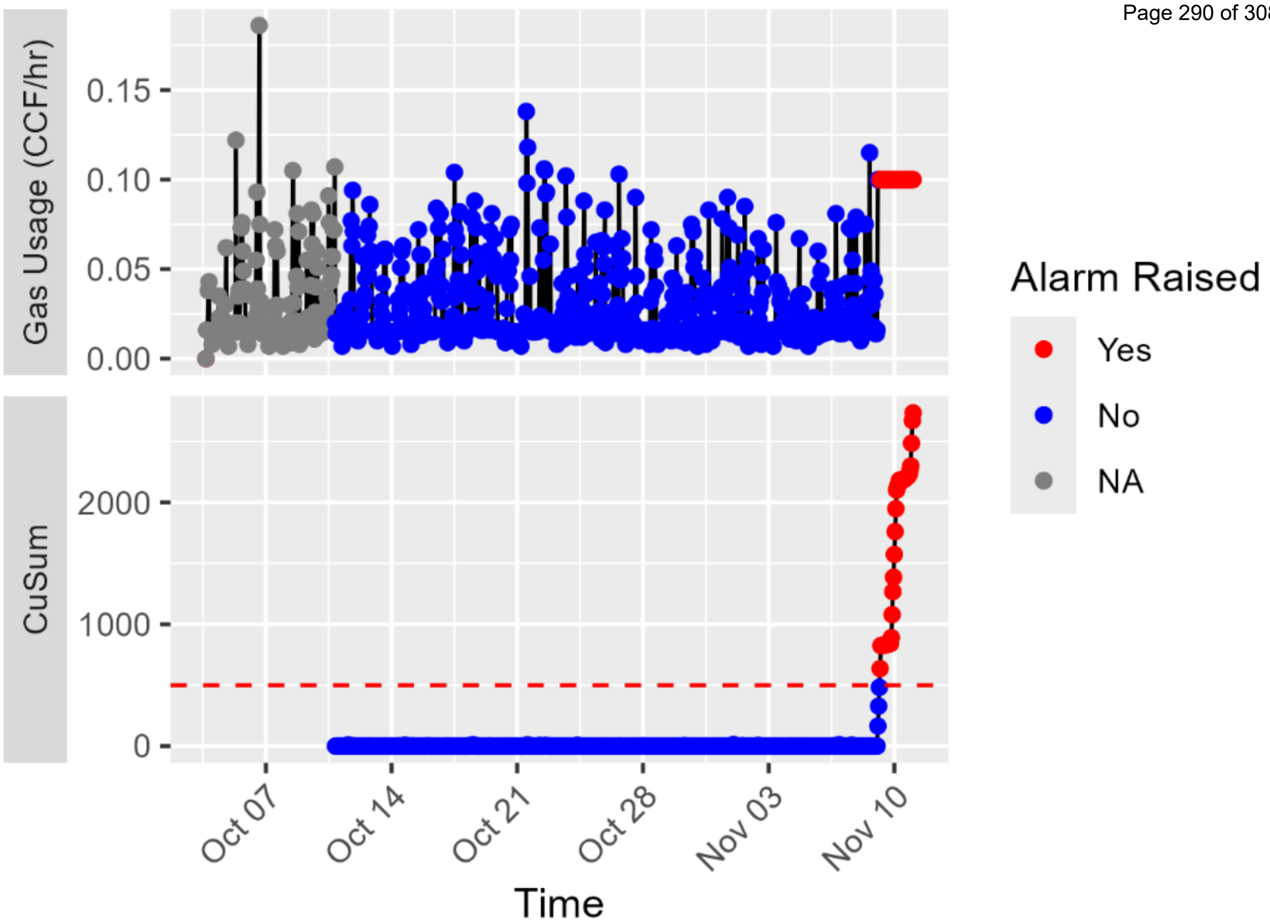
The project team will identify the high-frequency AMI data and the associated information (e.g., customer information, spatial location) provided by sponsors that will be used to develop the analysis approach. This will also include data management to ensure secure transfer, storage, and access.

After the data have been transferred and stored, the data will undergo data quality checks, corrections will be made as needed, and the data will be reviewed to ensure reliable modeling results.

The project team will develop appropriate statistical methods that can be used to model the outcomes. This includes the execution of the developed models to analyze data the data, check modeling assumptions, and generate tables and graphics.

Results

The team met with sponsors to refine the project scope and identify data sharing opportunities. The team also collected feedback on the current state of operators' AMI deployments and analytics programs. A data management plan has been established, and a SharePoint site has been set up to enable secure data transfer. The team also worked with utilization experts to obtain information about typical appliance gas consumption. The team converted this information (given in BTU/hr) to align with the consumption data units (CCF/hr.).



Simulated leak detection using the CUSUM method. A slow leak of 0.10 CCF was applied to a hypothetical consumer who left a burner valve open (shown by the constant consumption at the end). The gas consumption time series over several days is shown at the top. The CUSUM control chart is shown at the bottom. The CUSUM chart starts after the first week because it utilizes the consumer's history to monitor usage.

The team received two datasets and successfully explored the data to identify potential erroneous readings, such as negative consumption values and missing data. The team also created graphical summaries that illustrated the differences in customer behavior across months and on weekends vs weekdays. The results of these exploratory analyses illustrated potential considerations (e.g., weather) for building and improving an anomaly detection algorithm.

Using the provided data and input from conversations with sponsors, the team identified a set of principles for an anomaly detection algorithm. Using these principles, the team proposed and developed an approach to detect abnormal gas usage using a cumulative sum (CUSUM) control chart. The team demonstrated the usefulness of the completely tunable algorithm and shared the results of initial data exploration and algorithm development with sponsors, receiving positive feedback.

Status

The team will continue working on the algorithm and fine-tuning the parameters for each sponsor, so the resulting raised alarms align with the sensitivity of the sponsor's needs. The team will work to evaluate the algorithm if they are able to obtain ground truth data for field crew confirmed anomalies. The algorithm will be compared to current methods to evaluate whether or not these anomalies were detected by the CUSUM approach. The team anticipates creating a pre-pilot software application that communicates analysis results to operations teams. The team anticipates meeting with sponsors again who have shared data to tune the algorithm for specific needs and obtain feedback.

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OTD Operations Technology Development

Automated Field Personnel Training for Utilities

This project will investigate the commercializability of AI tools that securely retrieve information from a bounded set of domain-specific documents and generate responses to text, image, and speech queries from gas industry personnel, providing instant access to training that enables safe and efficient field operations.

Project Description

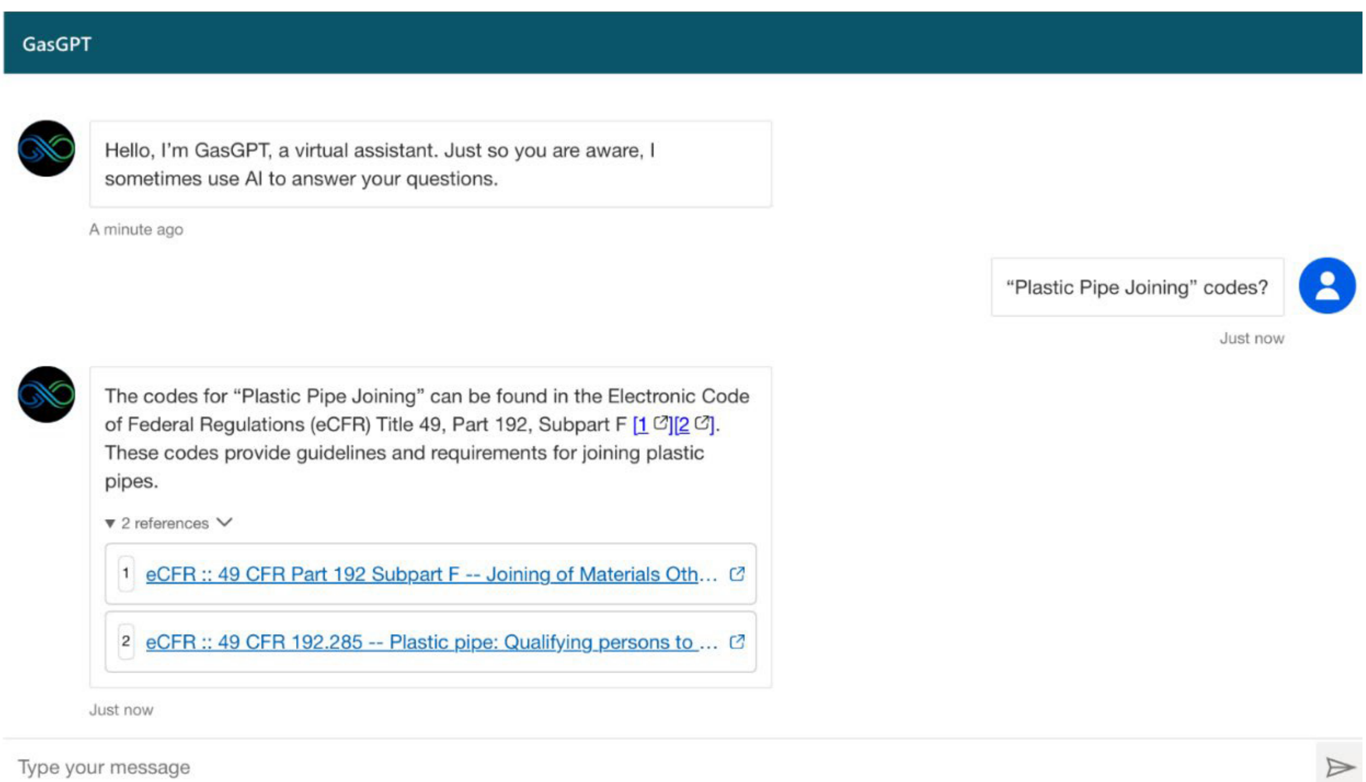
The utility industry is experiencing a change in the workforce and seeing higher attrition rates among relatively new employees. Additionally, there is often a time lag between hire dates and when there are openings in training facilities. As such, this project identified and investigated use cases for AI training, data to include in the training catalog, and test data/application accessibility.

Deliverables

The deliverables for this project included an investigation of use cases for AI training, data to include in the training catalog, a tested application, and a final report.

Benefits

The tool developed through this project will help expedite training of new personnel on how to perform work tasks and field activities quickly and effectively. This AI tool may help provide instant access to a company's procedures, best practices, industry standards, and other useful materials and processes.



Technical Concept & Approach

Specific tasks in this project include:

Use Case Analysis

This task focused on an investigation of the best uses for AI within gas companies. Understanding use cases defined both the input data required to develop AI assistants and the UI needed to access the output data. The initial use cases explored focused on the technical training of field personnel and gas engineers, while other use cases included delivering detailed information directly to field service personnel who encounter an unfamiliar component or configuration, or as a knowledge base for live technical support teams.

Data Source Identification & AI Configuration

This task will ensure data security and compliance by depending solely on provided data and mitigating risks associated with open internet-based solutions. To this end, a comprehensive system for the curation, cataloging, and maintenance of training data will be developed to manage input data and validate output.

Data/Application Accessibility

This task will focus on the requirement of easy access and usability as a prerequisite for any successful AI implementation. Empowering employees with easy access to relevant and up-to-date data and training materials should not only enhance efficiency and safety but also foster a culture of continuous learning and skill development within the organization. While a text-based chat window is the basic UI for AI and related systems, the accessibility of the output will determine its usefulness in everyday business processes. In addition to custom-coded implementation of the AI, the project team will also develop the application so that future APIs can be developed to enable implementations of this functionality into existing applications. Data security will be evaluated and tested at each step.

Results/Status

The project started in September 2024 with establishment of AI protocols and best practices. Use case analysis is in progress and the team is evaluating potential applications based on stakeholder feedback and technical viability.

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OTD Operations Technology Development

ALD Meta Analyses

This project's objective is to analyze data from advanced leak detection deployments both across and within operators. These analyses will provide insights into the correspondence of leak indications from different technologies and how the results differ across companies.

Project Description

This project will analyze the results of advanced leak detection and other leak survey deployments (e.g., walking survey) through the integration of data across and within operators to develop insights not otherwise available. This project will create a data repository of leak survey results, which can then be mined and analyzed to answer various questions around these deployments. The inclusion of the results of on-the-ground technician surveys to investigate ALD leak indications will provide additional data that can be used to evaluate and compare ALD deployments.

Deliverables

Results will be documented in a final report including methods, analysis, best practices, and areas of future work.

Benefits

The insights from this project can reveal the advantages and limitations of different leak survey methods and improve how they are deployed. Optimal ALD deployment approaches for a given operator may result in reduced technology costs and field crew time and improved system integrity.

Technical Concept & Approach

Specific tasks in this project include:

Identification of data sources and research questions with go/no-go

This task will identify the ALD and other survey data (e.g., on-the-ground investigations) that will be used to develop the analyses. This task will also include data management to ensure secure transfer, storage, and access. This task will conclude with a meeting with sponsors to discuss a go/no-go decision point to determine if the project should continue based on the data available.

Data management, cleaning, and processing

After the data has been transferred and stored, this task will focus on preparing the data for analysis by performing data quality checks and exploratory analyses. This step will involve removing or correcting data as needed, merging data sets, and controlling quality to ensure reliable modeling results.

Data mining, analysis, and modeling

The work in this task will be used to identify and develop appropriate data mining and/or statistical methods that can be used to explore the data and model the outcomes. This task will involve executing the mining techniques or models to analyze the data, check modeling assumptions, and generate tables and graphics.

Results

This project was launched in October 2024. During the kick-off meeting the team presented slides and created a 1-page information sheet with project information and requested data from sponsors.

The project team continues to work with sponsors to obtain the right type of data and enough data to make the project a success. Several sponsors have conveyed concerns about data privacy and the potential volume of data. While waiting to hear back from sponsors on data sharing, the team created a data management plan and explored data from another OTD project that could be used to support the project.

The team anticipates meeting with sponsors to discuss the go/no-go decision. The team will continue to correspond and have meetings with sponsors to facilitate data sharing. If enough data is recieved, the team anticipates beginning data cleaning, wrangling, and analysis steps.

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Center for Applied LDC AI Research

This program helps to understand and leverage value from the rapidly developing artificial intelligence (AI) tools for local distribution company business and operations. This program researches the opportunities presented by these novel technologies and also characterizes the challenges with integrating these tools into day-to-day operation, ultimately developing guidance for maximizing value.

Project Description

This program helps funders better understand and leverage value from the rapidly developing artificial intelligence (AI) tools. The latest surge of generative AI products based on Large Language Models (LLMs) continues to develop and mature rapidly. These technologies present risks to organizations such as misinformation, unintended consequences, and privacy concerns. However, these same technologies promise tremendous benefits, such as increased productivity, workforce development, and reduced costs. This program researches what is required to protect operators from AI threats and develop guidance for leveraging value. This project is designed to be flexible and adaptive to sponsor's needs; also, the content and topics of focus are adaptable to changes in the rapidly developing AI technology space.

Deliverables

The project consists of three main tasks: technology market research keeping atop the latest AI developments relevant for distribution companies and the energy industry, benchmarking the performance of generative AI tools against gas industry certification and qualification testing, and conducting a live, real-world demonstrations of AI's capabilities. Results will be documented in a final report.

Benefits

The research produced by this program informs gas operators on the latest AI tools, while identifying prime use cases where AI can be applied to improve business efficiency, safety, reliability, and regulatory compliance.

Technical Concept & Approach

Specific tasks in this project include:

Program Scoping

This task identifies the needs of funding members, including determining specific questions and current uses of stakeholders regarding generative AI. The project team conducts market research, gathering information on the recent technological breakthroughs, as well as commercial AI tools designed particularly for natural gas operators. The scoping task provides a solid foundation for understanding the needs, value propositions, and risk management opportunities available to the project stakeholders and will ultimately define the direction and focus of this research center.

Performance Benchmarking

Benchmarking is a technique used in the software industry to measure a system's performance and quantify improvements in new software versions or compare competing products. Generative AI tools, such as popular large language models including ChatGPT and Microsoft Copilot, are often benchmarked against tests, such as SATs, ACTs, and the Bar Exam, to compare the software's performance against humans. The team is instead benchmarking these common tools against gas industry certification and qualification tests to assess these tools' industry-specific knowledge. These benchmarks will create a quantitative measure of whether the fast-maturing AI tools are ready for use in distribution company operations.

Real-world Demonstration

This task demonstrates the use of AI for everyday activities relevant to OTD member company operations in a live webinar format, allowing member companies to ask questions and gain full understanding of state-of-the-art tools' abilities. The topics of these demonstrations range from prompt engineering large language models to using generative AI tools for data visualization and processing.

Results

The team delivered a presentation to project sponsors to communicate the project plan and allow for stakeholder feedback. A comprehensive review of the latest AI developments was conducted, and the findings were shared in two newsletters designed to keep stakeholders informed.

The first issue highlighted the increase in electricity consumption attributed to AI and the role of AI in predicting geohazards, noting that AI models outperform traditional methods in forecasting natural disasters. The second issue discussed the unified Microsoft Copilot interface for all generative AI tasks, discussed the key relevant facts about the unveiling of DeepSeek (a popular AI-driven app), and a chatbot created to associate third-party methane emissions detections to natural gas producers.

Finally, the benchmarking study was performed using OpenAI's ChatGPT on eight utility industry certification and training exams. These tests were asked repeatedly of the generative AI tool and the results were assessed for accuracy and consistency. Basic prompt engineering was also investigated, where information about the test context was also provided with the test question to the model. It was found that the standard tool performs exceptionally well on less technical tests, but struggles answering questions correctly that require more technical knowledge of natural gas and operations. These efforts collectively provide sponsors with valuable insights as they consider integrating AI further into their operations.

Status

This project will conclude in June 2025, and a subsequent phase is scheduled for the coming year.

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Training Computer Vision Models Using Simulated Components and Environments

This project seeks to explore and establish an affordable, effective workflow for expanding and augmenting training data related to computer vision and machine learning applications.

Project Description

The absence of large quantities of high-quality, labelled imagery often requires significant investment for image acquisition (either in terms of cost or labor) or precludes pursuits entirely. This project will create a foundational, use-case agnostic approach to exponentially expand available training data for computer vision model training by testing methods for synthesizing and integrating virtually created components and environments with real imagery.

Deliverables

The deliverables for this project include developing and testing computer vision methods that mix real and virtual elements, computer vision model training for each method developed and a final report.

Benefits

The project will establish affordable, efficient, and repeatable methods and workflows to augment and create training data for computer vision modelling where it is presently difficult or expensive to collect the necessary quantity of high-quality images.

Technical Concept & Approach

Specific tasks in this project include:

Data Collection/Acquisition and Literature Review

In this task, the team will collect real and artificial imagery of target assets and sites/environments. The team will explore the availability of open-source and commercial synthetic imagery of utilities assets. In tandem, the team will conduct a literature review on computer vision methods and approaches for integrating synthetic and real imagery, and approaches to modeling. All imagery for use in subsequent tasks will be collected during this task. The team will identify any methods or approaches that will be advantageous during modeling.

Virtual Environments Software Overview

The team will conduct a review of software related to digital twins and industrial simulations for the purpose of training computer vision models in virtual sites/environments. The team will assess how the selected software will interface with traditional computer vision model training approaches. At the conclusion of this task, the team will have identified methods and workflows for use in Synthetic Asset and Environments Development and Synthesis and Computer Vision Models Training Tasks.

Synthetic Asset and Environments Development and Synthesis

In this task will focus on the creation of synthetic utilities assets and sites/environments using the software identified in the previous task. Following these components' creation, they will be combined into a single scene for subsequent computer vision modelling and training. The synthetic assets and sites/environments will also be deployed separate from one another in Tasks - Real/Virtual Environments and Asset Synthesis and Computer Vision Models Training.

Real/Virtual Environments and Asset Synthesis

In this task, the team will focus on two distinct integrations: real imagery of an environment/site with synthetic components placed therein and virtual environment/site with real imagery superimposed therein. The outputs of these two efforts will each be used for individual computer vision model trainings.

Computer Vision Models Training

The computer vision models will be trained on the three distinct site and asset combinations: fully artificial environment/site with synthetic assets; fully artificial environment/site with real imagery of assets integrated; real environment/site with artificial assets integrated. Image labelling and model training will both take place during this task for all three scenarios.

Oil refinery environment developed using Unity, available for purchase in the Unity Asset Store. Oil Refinery 1 | 3D Industrial | Unity Asset Store

Performance Evaluation

This task the team will review model performance statistics from Computer Vision Models Training Task and test model deployments with real-world imagery.

Results

The project team established project methodologies and hosted a kickoff call with project sponsors, ensuring alignment for future and ongoing project work. The project team has completed the Data Collection and Acquisition. The need for high-quality training data is paramount, however, obtaining and annotating real-world data can be both time-consuming and costly. To address these challenges, the project team researchers are exploring synthetic data generation and parameterization, which can be used to efficiently create training data for computer vision models.

Status

The Virtual Environment Software Review is currently underway. This task encompasses evaluating and analyzing different software options for 3D modeling to determine the best fit for each method. The goal is to identify software that offers the necessary features, performance, and compatibility with our research goals.

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OTD Operations Technology Development

Evaluation of One Call Damage Prevention Software

The proposed project will evaluate different one-call and damage prevention software that is currently available on the market, highlighting important features and how those features can prevent pipeline damage.

Project Description

The project team will collect user feedback related to how on-call software systems may be improved and what software features are most important for operators. The project team will then use this information to interview software providers and characterize each software based on the features that are offered. This will assist operators seeking to upgrade their damage prevention software by supplying them with the information they need to make sure they are choosing the correct software for their specific purposes.

Deliverables

A final report will be prepared and reviewed with OTD sponsors. This report will detail all the one-call damage prevention software solutions that were investigated and highlight notable features of each software solution. Sponsors will have the opportunity to review the report before it is finalized.

Benefits

A modern damage prevention system that integrates into the operator's existing workflow can increase operator efficiency by allowing them to respond to potentially dangerous incidents faster. This project will help operators identify the practices, features, and overall software system that best works for them to prevent pipeline damage.

Technical Concept & Approach

Specific tasks in this project include:

Collect Sponsor Needs

The project team will identify SMEs at OTD member companies to cosult on the best practices currently in use for damage prevention software. SMEs will be interviewed to collect information related to how these systems are integrated into gas operations, dispatch, and record keeping. The project team will also collect user feedback related to how these software systems may be improved and what software features are most important for how they are used by the operators.

Damage Prevention Software Market Study

The project team will conduct a market study and interview software developers to discuss their damage prevention software systems, as they relate to the identified operator needs. The project team will collect information about each software solution and highlight the features that relate to the previously identified OTD sponsor needs.

Software Demonstrations

Once software platforms have been identified and deemed suitable for operator needs, the project team will organize online demonstrations of the software systems that OTD member sponsors and SMEs can attend. These demonstrations will allow time for questions and will be recorded to be viewed on the project page on the OTD website. The team will seek feedback from OTD sponsors about how these systems can be integrated into existing systems.

Results

The project team met with project sponsors to gather information on their current one-call ticket management and damage prevention software capabilities and practices. This involved meeting with sponsors' subject matter experts on damage prevention. The team identified and has received contact information from damage prevention and one-call ticket management software providers.

Status

In 2025 the project team plans to interview software providers, host software demonstrations and compile all findings into a final report.

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OTD Operations Technology Development

Commercialization of GSA Smart Pole

The objective of this project is to evaluate the integration of the GNSS Smart Automation (GSA) technology into a working commercial GNSS receiver, to assess the effectiveness and viability of the receiver, with the eventual goal of entering into a long-term license agreement.

Project Description

Improving the accuracy of location data has become increasingly crucial to the gas industry. OTD has invested in several project phases to develop the GNSS Smart Automations (GSA or "smart pole"), which resulted in a patent that was issued in August of 2021. This patented technology allows field crews who have minimal field training in collecting GNSS data to significantly increase the quality of their data through an automated data collection process. This project will work with the prospective commercializer to integrate the GSA technology into their GNSS receiver, field test it, and finalize terms for a commercial license.

Deliverables

The deliverables for this project include field demonstrations and tests of the technology in a working GNSS receiver prototype, a term for a commercial license agreement to market this technology, and a final report.

Benefits

This technology automates the process of collecting high-accuracy GNSS data by field crews, improving the quality and consistency of that data and making the process safer. This can also reduce the time and personnel needed to collect data.

GSA Devices shown with Phase 2 Enclosure and Features

Technical Concept & Approach

Specific tasks in this project include:

Knowledge Transfer

As the initial step in this task, the team will transfer knowledge related to the IP to integrate the software into the commercializer's GNSS receiver. The team will then implement and test the GSA technology in a working prototype.

Pilot Demonstration and Sponsor Feedback

During this task, the project team and commercializer will coordinate requirements gathering sessions with all sponsors in order to understand the expectations of the equipment and understand current needs. From there, 1-2 sponsors will be chosen to conduct pilot demonstrations to test deployment and usability in the field. The results will inform the commercialization planning. Pilots assume that 1-5 devices will be deployed in the field for short duration pilots (2 weeks to 2 months). Modifications from these assumptions may require scope or budget change orders.

Commercial Plan Development

The project team is will work with the commercializer to finalize the terms for a commercial license agreement, with the intent to successfully market this technology both within and outside the natural gas industry. The pilot demonstration will provide information for the commercialization task.

Results

GTI Energy, the commercializer, and a an OTD member company conducted on-site demonstration and testing of the GSA technology integrated into the commercializer's GNSS receiver, to evaluate performance and user experience. Demonstration and testing are expected to be conducted with Con Edison in late summer or fall of 2025.

The GSA technology as implemented in the commercializer's GNSS receiver has performed well in tests at GTI Energy and OTD members companies on the value and usability of the technology has been positive.

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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.

OTD Operations Technology Development

Reserve Strain Capacity Determination

Researchers worked 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 was to develop and demonstrate an information fusion network which captures interacting threats that act on high-strength steel transmission pipelines. The information fusion network incorporated 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 were twofold: accumulated strain estimates with uncertainty defined, and reserve strain capacity of the pipeline with uncertainty defined. Decision nodes in the network allowed scenario analysis for identifying suitable interventions to address reserve strain capacity of the pipelines of interest.

Deliverables

The deliverables from this project included 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 was 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

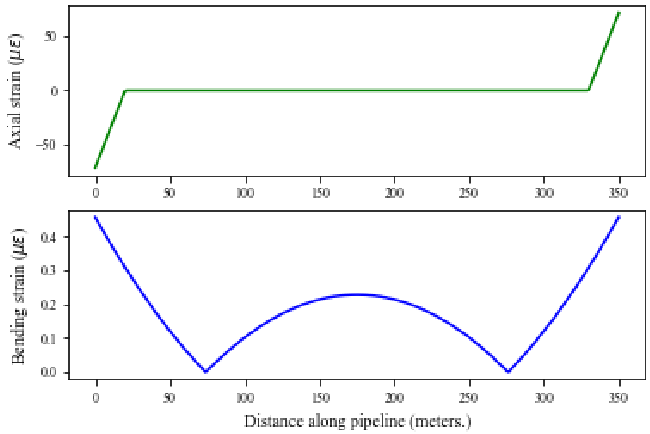
The project team conducted satellite measurements and Dimensional Image Correlation (DIC) measurements. The team used these measurements and any other available strain measurements to develop a framework for interpreting satellite ground movement data and converting to pipeline strain.

Results

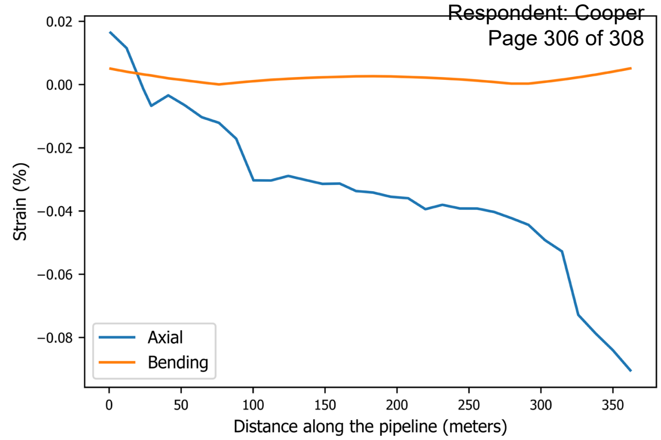
An information fusion network was developed to understand the uncertainty describing what has and is happening to a section of buried pipeline threatened by observed land movement. It is the first-of-its-kind model that demonstrates how to assemble a wealth of research, expertise, and observational data into a single model for assessing pipeline integrity to a geohazard. This information fusion network was created as a "proof of concept" model and is part of a larger initiative to enable data-driven decision making for pipeline systems.

The information fusion network integrates both pipeline and ground monitoring data. Strain capacity modelling required detailed metallurgical and historical information to predict the behavior of the pipeline's damage propagation under interacting threats. The strain demand modeling incorporated pipe-soil interaction, event-induced, and pre-event factors.

The two examples used in this project provide real solutions to observed land movement and strain measurements. These two predictive displacement



Axial and bending strain profiles from the deterministic model



Axial and bending strain profiles predicted by the information fusion network

solutions estimate the remaining strain and outline how one can use a "big picture" approach to model a pipeline integrity threat. Multiple technologies were used to observe change. These were incorporated to solve alternative axial and compressive strain predictive models. Competing models produced markedly different outcomes. Statistical methods helped in choosing the most likely prediction and best estimate of the remaining strain capacity in each pipeline example. The team used this to improve a prior hierarchical taxonomy of risk influencing factors (RIFs) that are relevant in a ground movement scenario. This improved taxonomy also provides the basis for how context and uncertainty should be considered in a strain-based pipeline integrity method to inform and improve the predictive tensile and compressive strain modelling demand outcome.

The network demonstrated its ability to synthesize different data sources into a single probabilistic assessment of strain demand to estimate the reserve strain margin. The information fusion network produced reasonable axial strain predictions, though the model still needs improvement to accurately predict bending strain. Nonetheless, this research represents a successful proof of concept model and offers promising opportunities for improvement. The preliminary results and lessons learned from this research have helped advance the state of the art in pipeline integrity modeling and will support the development of advanced decision-making tools for managing pipeline risk.

The models will allow operators to better conduct risk assessment and management programs, prioritize high-risk areas, and improve pipeline safety.

Status

This project is complete. The final report on Reserve Strain Capacity Determination was completed and released to OTD members in December 2024.

A follow-on project has been proposed to extend this research by improving understanding of how multiple pipeline threats interact and developing validated models to guide design codes and standards. The project involves collaboration between Arizona State University, University of Maryland, and GTI, with support from industry partners.

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