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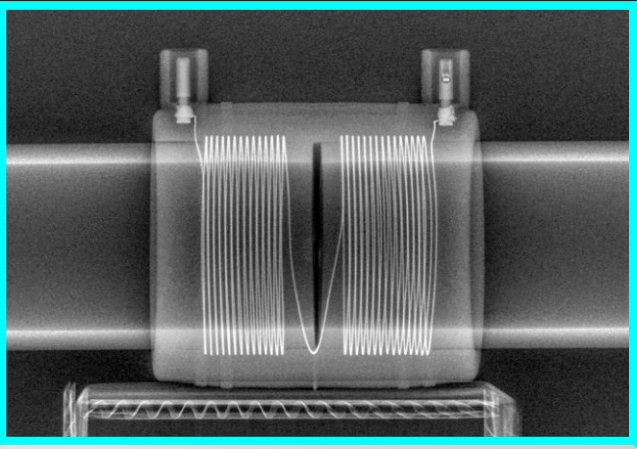

2023 Technology Briefs

Research, Development, and Demonstration Program

2023

NYSEARCH's Research, Development and Demonstration Program Report For Selected Projects

The Value of Collaborative R & D, the NYSEARCH model and its talented staff

The NYSEARCH Voluntary R & D program is a collaboration of members around North America.

The value of this collaborative comes from several distinct vantage points. Foremost is the leverage the individual members gain from: 1) combining financial investments, 2) utilizing a breadth of knowledge, 3) collectively seeking innovative solutions, 4) sharing lessons learned, and 5) integrating needs so that researchers and commercial entities can build solutions that attract an industry rather than an individual company.

The leverage ratio on a dollar ($) invested in a project for NYSEARCH members can range from 20:1 to 5:1 within the NYSEARCH group (depending on the size of the company). For some projects, leverage is even higher because of outside cofunding by agencies or technology providers (e.g. PHMSA/DOT or manufacturers).

Engaged, experienced members and skilled staff drive success in this collaboration. Members contribute information about solutions already tried, knowledge about other research, what is a 'State-of-the-Art' practice, where to go to find expertise, and past responses that did not address the need. Members also guide staff about their company's needs and what they know about industry initiatives. Similarly, staff research and attempt to stay abreast of international and industry solutions or challenges that influence R & D project development and management decisions.

When a collaborative group such as NYSEARCH seeks a technology provider or commercializer, the attraction to the provider goes beyond an injection of funding. They experience the ability to work with multiple companies simultaneously to: 1) develop product specifications, 2) analyze feasibility of concepts, 3) integrate expertise from different geographies, weather conditions and company practices, 4) maximize potential for a product or service that meets a wider industry need, 5) expand visibility of their offering, and, 6) efficiently address customer needs, constraints and opportunities. These advantages attract top notch technology providers who are willing to take risks and explore solutions that they otherwise would not have tried.

Research is risky. Not all R & D initiatives succeed. However, NYSEARCH and other collaboratives have had long term and short-term successes. These successes have come from members agreeing to focus on one challenge until it was overcome, knowing that they could leverage the investment on a risky venture with others and ultimately reduce the technical uncertainty and move to the next stage of opportunity. A particular member company who is excited about one concept can vette that concept with others and develop a better perspective on the application of a solution or the reason that a solution may work for one limited application and not another application.

Finally, the NYSEARCH collaborative is successful and provides value because it merges knowledgeable engineering/project management staff with R & D managers and operators from member LDCs who focus on what is practical. The NYSEARCH staff have a collective set of skills in the following areas: 1) project management, 2) strategic planning, 3) technology and needs assessments, 4) test design and implementation, 5) engineering analysis, 6) business management, 7) intellectual property management, and 8) contract administration. Most importantly, NYSEARCH staff are motivated to take initiative as deadlines in our work in R & D

contract management are self-imposed and require ability to flex as circumstances change. Staff are also trained to recognize success and failure and bring factual and timely recommendations to our sponsors.

Collectively, we have a mission to manage research in stages, justify R & D investments and demonstrate application to improve safety and operational decision-making. With this perspective, NYSEARCH is addressing critical needs in gas safety, low carbon fuels, reducing methane emissions and other important areas. NYSEARCH is working as efficiently as possible to contribute to the future of the gas industry and to provide environmentally sound and safe energy solutions.

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Report

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Emerging Fuels

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Technology Brief

Study on Changing Accuracy & Variability of Therm Zones Affecting Metering of New Gas Supplies

Description: **A study to determine how blending hydrogen into natural gas will change the gas properties which could influence the flow measurement performance of natural gas flow meters.**

Status: **Initial testing in Phase I is complete. Phase II with more extensive testing to identify trends of meter performance is in progress.**

BENEFITS

RNG injection and hydrogen blending in natural gas networks present a valuable solution for decarbonizing traditional energy systems, including heavy industry, heating, power generation, and transport, while enabling the transition to a low-carbon economy. Accurate gas composition and flow rate measurements are essential to ensure correct transactions and billings.

This testing will help determine the measurement errors when introducing hydrogen into the natural gas pipeline. Additionally, natural gas mixed with lower methane content seen in Renewable Natural Gas (RNG) is being tested for gas properties and the impact on energy content. This study will assist in identifying the need for any modifications to the billing process utilized currently by the Local Distribution Companies (LDC).

BACKGROUND

During NYSEARCH'S annual brainstorming session in 2021, the members identified that understanding the impact on the measurement of therm zones with the introduction of different gas supplies like RNG, hydrogen blending, etc., was a need. Typical metering technologies used for residential and commercial applications include rotary, turbine, and diaphragm flow meters which all measure the volume displacement of gas. Natural gas is measured by volume and this volume is then adjusted by applying a factor that reflects the heating value of gas contained in that volume.

The flow rate measured from the gas flow meter in homes and businesses is impacted by the gas composition, temperature of the gas, and gas pressure. Accurate measurements of these properties or reasonable assumptions are required to accurately convert the volumetric flow rate of the blended hydrogen and natural gas to an energy flow rate sold to an LDC customer.

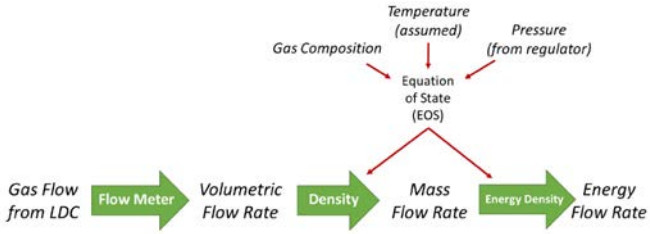

Figure 1: Measuring Natural Gas Energy Rate

Therefore, NYSEARCH developed a multi-phase project with Southwest Research Institute (SwRI) to determine if blending hydrogen with natural gas will change the residential and commercial natural gas meter accuracy. The ongoing project currently has two phases. The first phase, which was completed in April 2023 focused on initial tests to understand if and how the flow meter accuracy could change due to the presence of hydrogen. The data obtained in Phase I was used to plan a larger meter test set and more extensive testing in Phase II.

TECHNICAL APPROACH

The objective of the project is to characterize the impact of varying hydrogen blends on different

types of residential and commercial natural gas meters. The project is intended to gather the necessary gas property data that is required to calculate a mass flow rate from the residential flow meter output by simulating field conditions using a hydrogen test loop at the SwRI testing facility. The factors that are required to calculate the total energy that is billable from a metered volume include the flow rate, gas temperature, pressure, gas composition, and the Equation of State (EOS) to determine the gas properties, such as density and energy content.

To understand the gas property of blended hydrogen, the density of various natural gas and hydrogen blends will be measured and compared with existing EOS. Hydrogen and natural gas blends of 5% and 20% hydrogen are being tested as well as 5% and 20% hydrogen with RNG. This testing is accomplished with a high-pressure test cylinder for constant volume and using a highly precise scale with controlled temperature and pressure conditions. The detailed comparison of the standard EOS to the gas compositions will assist in the gas metering characteristics testing.

Gas meter characterization testing illustrates the performance of four common residential flow meters (rotary, turbine, diaphragm, and ultrasonic) with hydrogen blended in natural gas. This test helps inform the LDC's as they select meters for their distribution networks in hydrogen-blended natural gas grids.

Figure 2: Example of H_2 Blended NG Flow Rig

Each of the four flow meters for testing were incorporated into the SwRI flow test rig that was constructed for the project. The rig is designed to provide a homogenous and steady flow of test gases.

From these tests, the funders of the project are being provided with an extensive evaluation of common natural gas flow meters' performance with hydrogen concentrations up to 20% by volume. Additionally, systematic trends in measurement are being quantified and an analysis of meter performance across the flow range at each concentration is being provided.

PROGRAM STATUS

Phase I of this project is complete. Although the testing was successful, the test program produced results that require additional investigation based on the natural gas flow meter technology. While one of the technology's accuracies was generally unaffected by the presence of hydrogen the other three technologies showed some error. Therefore, additional testing is being conducted to determine whether the measured effect comes from hydrogen or other factors and provide the repeatability of the meters under the blended gases.

Phase II is further expanding the hydrogen content and meter types for testing, adding a test point of 25% hydrogen to aid in establishing a trend, and includes another variable in the EOS; the heat of combustion.

Highlights

- Evaluates residential and commercial meters selected by funders.
- Assess how existing natural gas flow meters could be affected by blending hydrogen and natural gas/RNG.
- Assists in identifying modifications needed for the utility billing process as a result of the presence of hydrogen blends in the gas transported by LDC infrastructure.

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Hydrogen-Natural Gas Living Lab

Description: **A project to test in live conditions the impacts of higher concentrations of blended H2 on gas piping materials and a wide range of gas engineering aspects and operations**

Status: **Design specifications, constructions requirements, permits and other contractual documents are being put into place by SoCal Gas, the Living Lab host and project lead. NYSEARCH funders are providing input and materials that influence design selection, test plans and samples for use.**

BENEFITS

By displacing natural gas with blended hydrogen, there is a potential for significant reduction in Greenhouse Gas Emissions (GHGs). Blending as a hydrogen delivery method, can defray the cost of building dedicated hydrogen pipelines or other costly delivery infrastructure especially during early market development. Blended hydrogen has the potential to enhance energy efficiency and resiliency in delivering renewable and non-renewable fuels.

This project explores and validates feasibility studies that have already been performed by collecting data in live conditions for a range of issues and systems that the blended hydrogen (at higher volume percentage concentrations: 25 vol% - 35 vol %) could face. The 'Living Laboratory' concept is designed to take lab scale concepts to validation without the need for full pilot test structures and by taking advantage of existing test expertise, facilities and scaleup opportunities.

BACKGROUND

Hydrogen blending has the potential to be disruptive in the energy space and utilities need to identify and overcome technical challenges to ensure people's safety as well as provide a cleaner and greener fuel. Transformational research is needed to educate gas companies on how to maintain security of the gas supply to our homes and businesses, as the country moves away from natural gas that has been the bedrock of the US energy system for almost a century. Blending hydrogen into natural gas pipeline networks has also been proposed as a means of delivering pure hydrogen to markets, using separation and purification technologies downstream to extract hydrogen from the natural gas blend close to the point of end use. SoCalGas has experience with small scale testing of hydrogen blends at <20 vol% and with participation in a range of low carbon fuels projects. In this NYSEARCH consortium, materials and test specifications can be shared by other members and then used in the SoCalGas test program.

TECHNICAL APPROACH

The objective is to demonstrate, collect and analyze data, and report on the impacts of hydrogen blending at higher percentages and in medium and high-pressure systems by monitoring and evaluating conditions that affect safety, maintenance, and emergency response related to the gas distribution infrastructure.

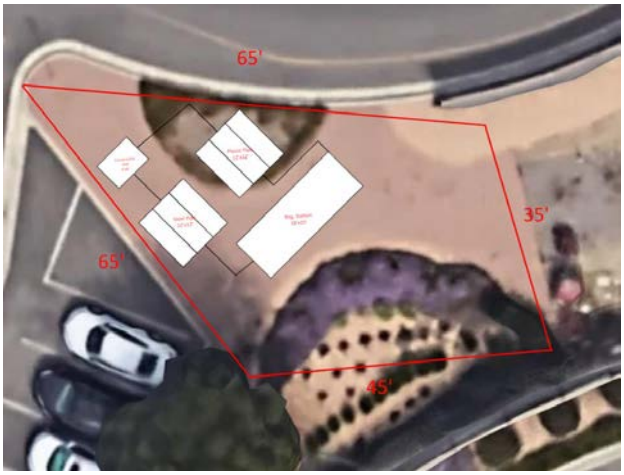

Figure 1: Rough layout of Living Lab being constructed at SoCalGas' Pico Rivera facility

A partial list of project activities include: testing the performance of the hydrogen blending skid, assessing emissions impacts when using hydrogen blends, impact on pipeline materials and components, leak detection equipment applicability and performance, metering and regulation and safety/response procedures.

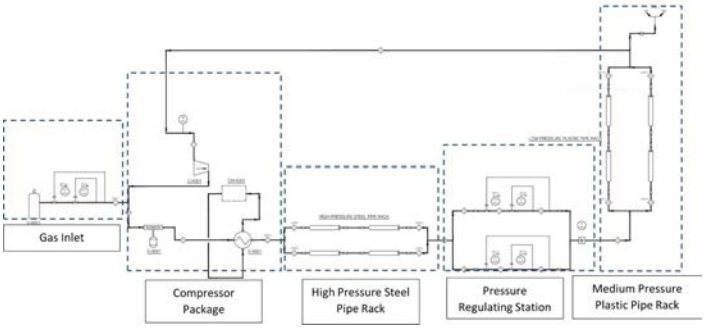

Figure 2: Conceptual Process Flow Diagram

PROGRAM STATUS

SoCalGas is leading the engineering design, construction, and testing data collection throughout the two-year demonstration. The SoCalGas team and the NYSEARCH Project Manager have been working collectively with other NYSEARCH funders on the specifications for the test site. A test plan for materials testing and leak detector evaluation is also being circulated for input by the funding members.

SoCalGas is working with third parties on engineering design and compressor assembly and installation. They are also working on the necessary permitting with the city of Pico Rivera. Thus, the site will likely be under construction and not live for testing until August 2024. At that time or sooner, commissioning will commence the test phase.

Highlights

- Living lab approach builds on previous feasibility studies and laboratory analyses by moving to near full-scale deployment
- SoCalGas serves as the industry leader in this project and host using their facilities, in-house expertise, third party contractors and regulatory drivers
- NYSEARCH's role in the Living Lab is to provide funding and input through its diverse membership to broaden the visibility and lessons learned from the project
- NYSEARCH members provide input and gain valuable lessons learned through a large investment of SoCalGas

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Technology Brief

Impact of H2 Enriched Natural Gas (HENG) on Feedstock for Liquified Natural Gas Liquefaction

Description: **Define and evaluate the impacts of HENG on plant materials and plant operations, and determine potential feedstock pretreatment or hydrogen rejection options.**

Status: **Thermodynamic analysis of the LNG Plant and materials of construction analysis are complete.**

BENEFITS

This project provides Liquified Natural Gas (LNG) plant operators and decision-makers the ability to ascertain what the best procedures and pretreatment / retrofit options could be. It also provides a technical basis for pursuing rate-recovery for necessary retrofits to meet future feedstock requirements. Also, this project provides operators with access to specific mitigation options that could be applied to their LNG facility.

BACKGROUND

There are a number of Liquefied Natural Gas (LNG) Plants connected to natural gas (NG) systems in the United States. Several are in the Northeast, particularly Massachusetts, Connecticut, and Rhode Island as well as New Jersey, New York, and Pennsylvania. There are also plants in the Mid-Atlantic states, in the South, and in California. Gas customers in some of these regions, at critical times, rely on peak-shaving LNG to meet their natural gas needs. As decarbonization becomes more prevalent and natural gas systems are converted to lower carbon fuels, the use of blended hydrogen (H2) up to 20% blends or pure H2, will become more prevalent. With that in mind, the natural gas industry and its R & D organizations are exploring a range of issues related to LDC infrastructure, appliances, materials compatibility, etc. To date, there has not been a focus on the impact of H2 on LNG Liquefaction and corresponding mitigation options.

In November 2021, the Northeast Gas Association (NGA) conducted an H2-Enriched NG Technical Workshop for its members and members of the American Gas Association (AGA) LNG Committee to explore LNG peak-shaving plant operations.

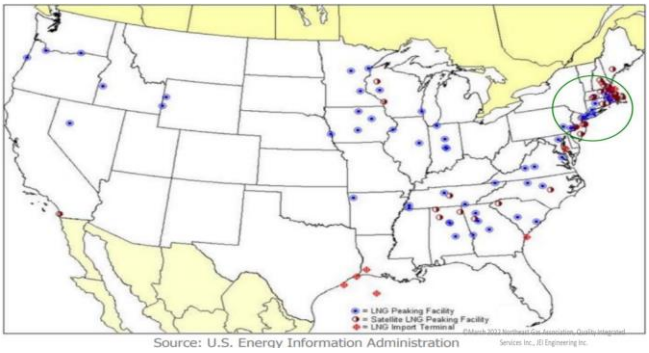

Figure 1: LNG Plant Locations in the US

Those companies, some of which are members of NYSEARCH, strongly endorsed the idea that the industry needs to consider several challenges and mitigation measures should natural gas pipeline system liquefaction include H2 at even low concentrations such as 1% by volume. Thus, the basis for a multi-phased research program was formed.

Some of the technical hurdles and likely potential challenges identified for using blended H2 for LNG Liquefaction include: 1) H2, as a gas, can compromise the liquefaction process, 2) the Boil-Off-Gas (BOG) management process that is inherent in tank storage systems could be compromised by concentrations of H2 and compressibility of BOG becomes an issue, and, 3) storage vessels, gaskets, and gas piping could be affected through H2 embrittlement. Thus, the idea of liquefying blends of HENG is a challenge. Procedures and feedstock pretreatment equipment may need to be changed to isolate the H2. Thus, this project considered the challenges as well as feedstock pretreatment options.

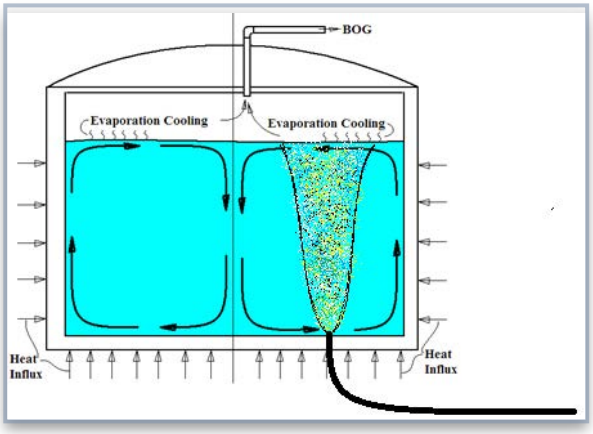

Figure 1: Bottom fill of LNG tank

TECHNICAL APPROACH

The objectives of this project include: 1) defining and evaluating the impacts of HENG on plant materials and plant operations, and 2) determining potential feedstock pretreatment or hydrogen rejection options.

At the outset, NYSEARCH, with project partner Quality Integrated Services (QIS), collected data from the NGA and NYSEARCH funders' facilities and developed an inventory of materials that would be exposed to HENG. Through the use of questionnaires, QIS tabulated, evaluated, and reported the results.

Next, a detailed thermodynamic study was conducted to evaluate every component and process from the inlet valve to the tail gas outlet valve of the identified LNG plant(s). Four (4) plants were evaluated from member facilities for further study. The four (4) identified member facilities range from vintage LNG plants to new construction. It is important to note that the vintage facilities being analyzed meant that they were placed in service in the 1960s and 1970s. Since commissioning at that time, some of the plant data is likely to have changed as equipment was updated and maintenance was performed. Data collection at these vintage facilities is necessary to reflect any changes and ensure thorough analyses. QIS is utilizing two (2) selected codes, ASME B31.3, and ASME B31.12, as reference documents for evaluating the plants. In addition, computations are being performed to determine the potential quantity of H2 in BOG as well as in LNG.

In this continuing work, NYSEARCH and QIS is ascertaining what additional R & D is necessary by investigating a range of topics including the adequacy of materials, compression of HENG mixtures, maximum acceptable thresholds (if any) of HENG in feedstocks, gas detection and fire protection system issues and spontaneous combustion concerns.

PROGRAM STATUS

This project is likely the first thorough technical study of specific issues that are identified from actual facility information as it pertains to HENG. The thermodynamic analysis for the LNG plant and the materials of construction analysis are complete. Four (4) selected member plants are being inventoried and evaluated to provide in-depth analyses.

A future phase is planned to focus on how to mitigate the negative effects HENG feed-gas may have on LNG facilities, and a range of pretreatment, recovery, and reinjection options will be investigated. This work will focus ultimately on mitigation measures associated with BOG management as well as previously identified challenges. The work will engage with SMEs in the design and building of LNG plants and in cryogenic process systems.

Highlights

- Thermodynamic analysis is complete.
- LNG plant 'materials of construction' analysis is complete.
- Four (4) selected LNG plants are being inventoried and evaluated to collect data for further risk analysis.

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Technology Brief

Common RNG Interconnection Skid Development for Utilities

Description: **Develop a common engineering design for the RNG interconnection process that could provide utilities and RNG producers significant savings and reduce costs.**

Status: **The project deliverables, including engineering design package, equipment and instrumentation database, Bill of Materials, and cost estimator have been completed and are being socialized for funders. This product is being considered for sale to non-members on the www.nysearch.org website.**

BENEFITS

As the Renewable Natural Gas (RNG) industry grows and decarbonization efforts remain a high priority for LDC's, the demand for interconnecting with existing natural gas infrastructure will continue to increase. The benefit of this project is to provide a standard RNG interconnect skid design that could be incorporated by natural gas utility companies to reduce design efforts and cost as they are approached by RNG companies and biogas producers to inject into their existing systems. Developing a common engineering design could provide gas utilities and RNG producers significant savings and open more opportunities to utilize RNG which may otherwise have been cost-prohibitive.

BACKGROUND

One of the challenges identified by the NYSEARCH consortium has been focused on interconnection from a biogas producer to receive RNG into the utility system. The interconnection process involves evaluating economics (unique tariff scenarios), gas quality management, and customized piping and instrumentation design to meet engineering standards. Currently, many utilities have or are in the process of developing their own interconnect designs. This approach works for some utilities. At the request of NYSEARCH members, avenues were pursued to standardize the RNG interconnection process and reduce cost.

NYSEARCH identified Campos EPC (CEPC) as a leading engineering and construction company in the space of decarbonization and approached them with the RNG interconnection challenges facing utilities today. The engineering design database and an initial customizable skid design are the first steps to developing a Common RNG Interconnection Skid for utilities. CEPC developed two standard interconnect skid designs, one open-air and the other enclosed. These designs would leverage a database of various design options such as instrumentation, measurement, regulation, gas quality analysis, and safety measures to allow a plug-and-play approach that utilities can work with to develop an interconnect skid that best fits their needs while minimizing costs.

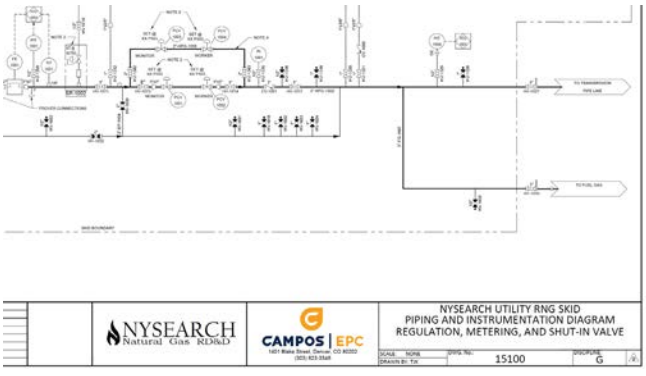

Figure 1. Snapshot of a Piping & Instrumentation Diagram of NYSEARCH RNG Interconnection design

TECHNICAL APPROACH

The objective of this project was to generate a foundational RNG interconnection skid design

alongside an equipment & instrumentation database for which utilities can modify the standardized design as they see fit.

With varying needs across different natural gas utilities, the goal of this design was to accommodate many different scenarios that may occur. Thus, the skid was designed to account for a wide range of pressures, flow rates, and temperatures without the need for significantly altering the design.

To gain full understanding of the needs of the several natural gas utilities within the NYSEARCH funder group, Campos EPC (CEPC) sent out a comprehensive survey to these utilities asking about their specific design needs. The questions in this survey were related to equipment preferences, expected gas process conditions, electrical requirements, and structural requirements. Also, several NYSEARCH members who are actively commissioning RNG interconnection points, were interviewed to determine the specific challenges encountered during RNG interconnection. From these discussions, a common RNG interconnection design database was determined as a viable solution to promote consistent implementation processes for LDC's. Due to differing design needs from the utilities, not all items in the survey were able to be accounted for on this skid design.

The engineering drawings and models (see Figure 2) were all created as a NYSEARCH standard, and the equipment and instrumentation database (see Figure 3) was deployed. NYSEARCH funders attended online tutorials to learn how to navigate the

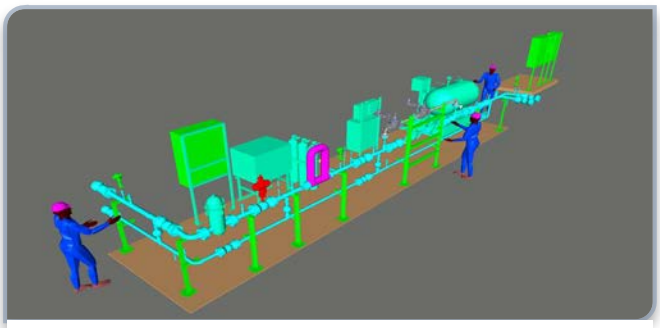

Figure 2. 3D model of open-air skid design

database and leverage the standardized designs to customize the RNG interconnection to utility specific needs and requirements.

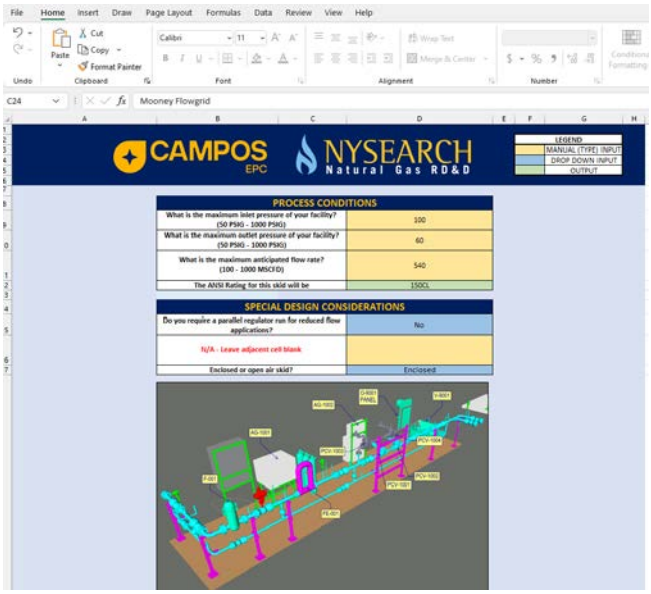

Figure 3. Equipment and instrumentation database developed as an Excel spreadsheet

PROGRAM STATUS

The engineering package with all P&ID's, electrical, structural, Bill of Materials, equipment & instrumentation database, cost estimator has been reviewed, approved, and delivered. Further, online tutorials have been completed with the NYSEARCH funders to train individuals on how to utilize the database in conjunction with the standardized designs.

Highlights

- An industry standard for RNG Interconnection design process to streamline engineering, design, and construction providing significant cost savings.
- NYSEARCH is working to potentially offer the design and database as a product for sale to non-members on the www.nysearch.org website.

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Technology Brief

Renewable Natural Gas Interchangeability Research for Residential Appliances

Description: **Evaluation of varying Renewable Natural Gas (RNG) compositions on performance of residential appliances.**

Status: **Appliance testing is complete. NYSEARCH Range™ *Plus* available on www.nysearch.org**

BENEFITS

The addition of new RNG supplies (from aerobic digestion, power-to-gas etc.) is expected to increase, leading to wider range of gas compositions. This NYSEARCH project performed a comprehensive evaluation of the impact of varying gas composition on the performance of residential appliances to determine the potential extent of sensitive appliances being affected. This can aid gas companies, manufacturers, and installers in optimizing appliance adjustments for current and future RNG supplies and to further promote regular maintenance. This will also help advance a wider range of gas compositions that can be managed through the updated NYSEARCH RANGE™ model.

This projects also aimed to address the ongoing dialogue on the technical limits of siloxanes in renewable natural gas. Assessment of siloxane impacts on sensitive natural gas end-use equipment will help to specify technically-sound limits.

BACKGROUND

NYSEARCH has a history of investigating the impacts of changing gas supplies through its project #765 known as the 'Gas Interchangeability for Residential Appliances' study. In that project, the goal was to evaluate the impact of changing gas composition on the performance of in-service residential appliances. Through evaluations of the performance of customer appliances' and subsequent laboratory testing and modeling, the NYSEARCH RANGE™ model (see Figure 1) was developed. Several gas companies in US and Canada are using this tool as an alternative to various empirical indices to assess performance of appliances with different gas compositions and to aid gas tariff discussions on thresholds when new supplies are offered.

Figure 1: Screenshot of NYSEARCH RANGE™ model

With broader, more widespread interest in the RNG, additional analysis was required to expand the NYSEARCH RANGE™ model. In addition to exploring flashback and lower Wobbe number effects, there is a need to look further at work on blended Hydrogen in power-to-gas applications.

In addition, given the interest in setting up of limits for Siloxane in RNG; there was potential to

TECHNICAL APPROACH

The objective of the project is to study the impact of trace constituents in Renewable Natural Gas and traditional pipeline gas on LDC infrastructure and customer appliances. This project will be carried out in two tasks as described below:

Task 1: Gap Analysis: DNV-GL surveyed the project sponsors for data of US networks and appliances. Using their expertise from over (10) years of biomethane risk assessments for UK gas networks, DNV-GL assembled a list of possible RNG trace constituents that they are aware of or believe to be deleterious to network equipment and materials (metallic, polymeric, and elastomeric). The list includes a combination of trace constituents that can cause problems during certain network operations, e.g., pressure regulation, in-grid storage, in-grid compression, odorization, etc. A similar analysis was conducted for consumer appliances as part of Task 1. The result is a list of trace constituents that are believed to be damaging and cause problems during or after combustion.

Figure 2. Extraction of HDPE pipe sample prepared for trace constituent exposure testing

DNV-GL is recommending which type of impact study i.e., network infrastructure, network operations, or consumer appliances are likely to be most critical in terms of trace constituent concentration.

Figure 3. Water bath with extracted pipe samples submerged in testing agents

Task 2: Experimental Test Program: The test program (see Figure 2 and 3) is using an optimized design to examine the effect of the trace constituents on the properties of the polymer/elastomer. For this experimental design and for the selected materials, mechanical properties are measured before and after soaking in a test fluid that contains both a high and low concentration of the short-listed trace constituents. Results from this experimental approach will help evaluate relative effect of each trace constituent and give insights into any interaction parameters.

PROGRAM STATUS

DNV-GL has completed the gap analysis and identified a list of trace constituents that need experimental testing to determine trigger limits. Materials testing is complete and appliance testing is underway. Complete results for the project are anticipated for first quarter of 2024.

Highlights

- A set of deleterious trace constituents found in RNG are being tested to establish trigger limits to maintain the integrity of LDC infrastructure and evaluate residential appliance performance
- The data gained from this study will provide supporting scientific evidence needed to confidently establish limits for the industry as RNG opportunities

For more information contact:
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NGA NORTHEAST GAS ASSOCIATION
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Technology Brief

Study on Impact of Trace Constituents in RNG

Description: **A study comprised of a gap analysis followed by laboratory testing to evaluate effects of trace constituents in RNG on gas infrastructure and residential appliances**

Status: **Materials testing of select RNG trace constituents is complete and appliance testing is underway.**

BENEFITS

This project aims to reduce the uncertainties and variation in limits set by different utilities for the trace constituents found in Renewable Natural Gas (RNG) by providing scientific data to back up the trigger limit recommendations. Considering growing demand for RNG production and injection into distribution infrastructure in North America, the testing should help both producers and developers to help determine the optimum upgrading and measurement system for biomethane. For LDCs, it will aid decision making and help advance specifications to address safety and reliability issues.
The gap analysis will help identify deleterious constituents and/or group of constituents to gas infrastructure and appliances.

BACKGROUND

To reduce carbon emissions and move towards a more sustainable energy supply, there is an increasing trend of using Renewable Natural Gas (RNG) in the United States and Canada. Depending on the source (See Figure 1), RNG can contain compounds that are not present in traditionally distributed natural gas such as ammonia, halocarbons, siloxanes, biologicals etc. One of the requests by our members during a NYSEARCH Decarbonization Workshop was to conduct additional research to determine the appropriate levels of some of the contaminants in RNG. NYSEARCH was directed to establish the science-based limits as needed for the RNG trace constituents. Our initial survey led to limited documented scientific evidence on the appropriate levels of trace constituents in pipeline quality gas. Also, the trace constituents list considered for further evaluation includes contaminants that are present in natural gas and for which there are network limits, e.g., mercury, hydrogen sulfide and moisture. This is because some limits set for natural gas are based on empirical data. They are either missing scientific evidence or are based on measurements now deemed obsolete such as historical analytical capabilities.

DNV-GL has conducted two risk assessments for NYSEARCH members on Impact of Corrosive substances on distribution infrastructure and the effects of Siloxanes on residential gas appliances and gas engines.

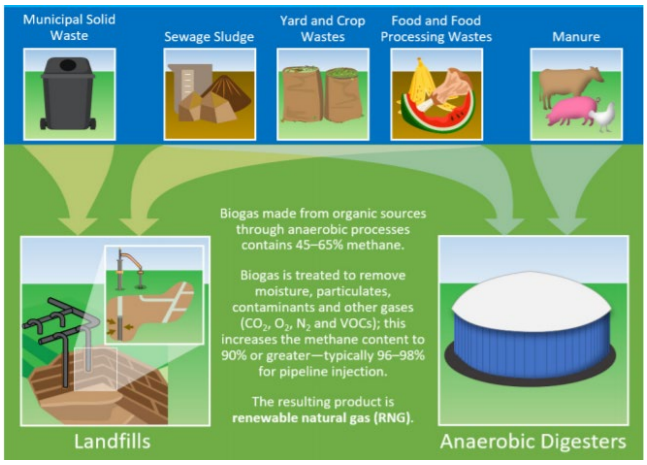

Figure 1. Various RNG Sources and trace constituents

DNV-GL has also tested for Trace Constituents for gas in the networks in Europe. DNV-GL's expertise in natural gas networks and RNG production led them to conclude that the impact of any individual contaminant should not be considered in isolation due to fact that they will not be released in the network one at a time. Thus, a gap analysis was needed before limits can be set for individual constituents.

TECHNICAL APPROACH

The objective of the project is to study the impact of trace constituents in Renewable Natural Gas and traditional pipeline gas on LDC infrastructure and customer appliances. This project will be carried out in two tasks as described below:

Task 1: Gap Analysis: DNV-GL surveyed the project sponsors for data of US networks and appliances. Using their expertise from over (10) years of biomethane risk assessments for UK gas networks, DNV-GL assembled a list of possible RNG trace constituents that they are aware of or believe to be deleterious to network equipment and materials (metallic, polymeric, and elastomeric). The list includes a combination of trace constituents that can cause problems during certain network operations, e.g., pressure regulation, in-grid storage, in-grid compression, odorization, etc. A similar analysis was conducted for consumer appliances as part of Task 1. The result is a list of trace constituents that are believed to be damaging and cause problems during or after combustion.

Figure 2. Extraction of HDPE pipe sample prepared for trace constituent exposure testing

DNV-GL is recommending which type of impact study i.e., network infrastructure, network operations, or consumer appliances are likely to be most critical in terms of trace constituent concentration.

Figure 3. Water bath with extracted pipe samples submerged in testing agents

Task 2: Experimental Test Program: The test program (see Figure 2 and 3) is using an optimized design to examine the effect of the trace constituents on the properties of the polymer/elastomer. For this experimental design and for the selected materials, mechanical properties are measured before and after soaking in a test fluid that contains both a high and low concentration of the short-listed trace constituents. Results from this experimental approach will help evaluate relative effect of each trace constituent and give insights into any interaction parameters.

PROGRAM STATUS

DNV-GL has completed the gap analysis and identified a list of trace constituents that need experimental testing to determine trigger limits. Materials testing is complete and appliance testing is underway. Complete results for the project are anticipated for first quarter of 2024.

Highlights

- A set of deleterious trace constituents found in RNG are being tested to establish trigger limits to maintain the integrity of LDC infrastructure and evaluate residential appliance performance
- The data gained from this study will provide supporting scientific evidence needed to confidently establish limits for the industry as RNG opportunities

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NGA NORTHEAST GAS ASSOCIATION
NYSEARCH

Technology Brief

Scaling of Microbial Power to Gas (P2G) Conversion for Long Term Operation

Description: **To test and identify limitations and successes in the long-term operation of microbial electromethanogenesis with intermittent electricity supply cycles.**

Status: **Intermittency testing has concluded successfully - a next phase of work to advance the electrochemical design of the microbial P2G reactor is being examined.**

BENEFITS

As the natural gas industry is beginning to shift towards decarbonization and investigating the potential of emerging fuels, NYSEARCH is taking the opportunity to investigate an innovative energy storage solution and an unconventional method to create a renewable resource through microbial electromethanogenesis. There is a need and a business opportunity for long-term storage of electrical energy, especially as renewably produced energy becomes more abundant. This innovative microbial power-to-gas platform provides the potential to produce methane that can be upgraded as renewable natural gas (RNG) and injected into existing infrastructure.

Moreover, conversion of power to natural gas from CO_2 is an emerging platform for producing carbon-neutral methane, which also provides an important business opportunity for Local Distribution Companies (LDC's).

BACKGROUND

This research addresses the molecular, cellular and metabolic processes associated with a long-term operation of an electromethanogenic system; converting electrical energy plus CO_2 + H_2 into methane at high rates.–Electricity produced from renewables is becoming a more abundant and common resource. However, currently electricity produced from renewables fluctuates and is inevitably lost when not used following production. One desirable and promising path to store intermittent, renewable electrical energy is Power-to-Gas technology, where electricity is converted into methane or hydrogen, which is immediately compatible with today's energy infrastructure. Conventional power-to-gas technologies produce hydrogen or methane from electrochemical processes with technical limitations. Further, hydrogen is not an ideal chemical storage compound with its low energy density.

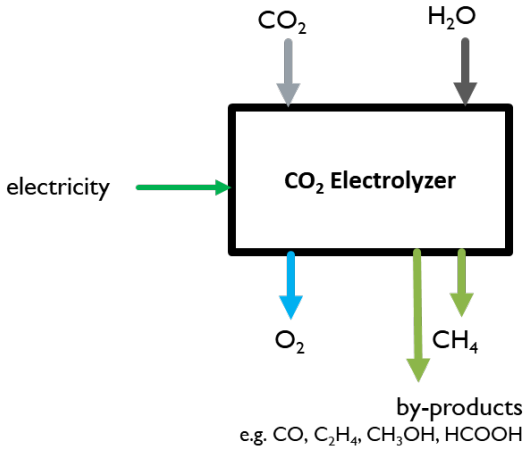

Figure 1. Traditional Power to Gas (P2G) process

Microbial electromethanogenesis is emerging as a viable technology platform for converting electrical energy into natural gas by reduction reactions at high selectivity and efficiency at the cathode.

The current state-of-the-art in microbial Power-to-Gas technology includes a traditional water electrolyzer that generates hydrogen which is then pumped into an anaerobic digestor to upgrade methane into biogas (see Figure 2). The cost and complexity of these electrolyzers represent severe technical and cost limitations.

The basis of this project explores Stanford University's innovation where microbes directly consume CO_2 and hydrogen, which is

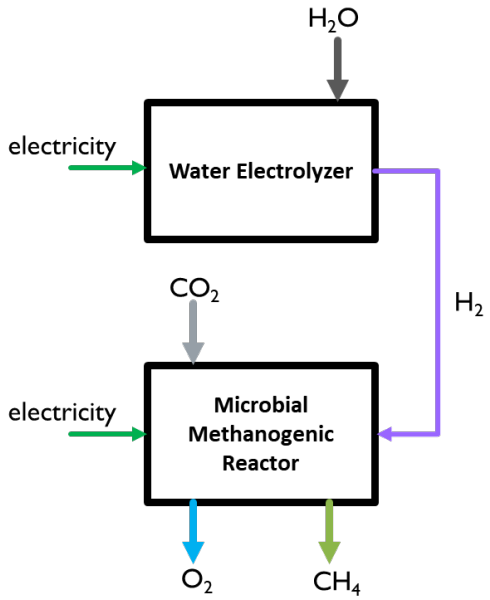

Figure 2. Current State-of-the-Art microbial P2G process

generated at the cathode (created from low-cost sustainable metals) and is immediately consumed, providing a viable alternative beyond batteries for long-term and seasonal energy storage. The innovation of an integrated microbial power-to-gas conversion is that it is a carbon neutral process (uses atmospheric CO_2 as a substrate) and one where hydrogen gas does not need to be transferred as seen in the current state-of-the-art technology. This phenomenon significantly reduces capital and operating costs.

TECHNICAL APPROACH

Figure 3 depicts the electromethanogenesis process being evaluated in this project. Stanford University's recent work on microbial electro-methanogenesis provides the first molecular understanding of how microbes take up electrons from the cathode. They have demonstrated how a microbial electrosynthesis platform can be integrated with advanced catalysts to efficiently funnel electrons and enhance the conversion rate from power to gas [current to methane]. NYSEARCH and Stanford are working to better understand the long-term effects that the microbes experience as living agents of electrochemical reactors.

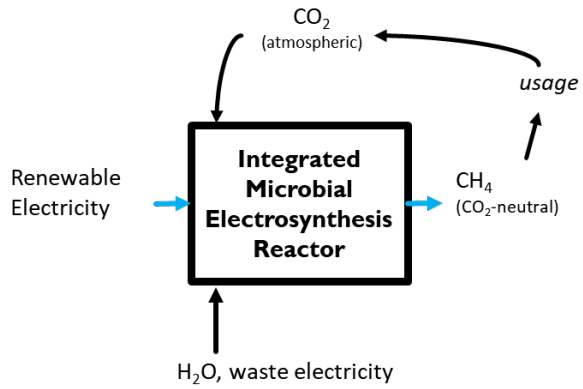

Figure 3. Integrated electromethanogenesis process

Specifically, this research is improving the microbial capacities associated with long-term operation of an electric power-to-gas operation. Stanford is investigating factors impacting long term performance such as microbial viability, performance of the microbes with intermittent supplies of renewable electricity, and microbial compatibility with different electrode materials.

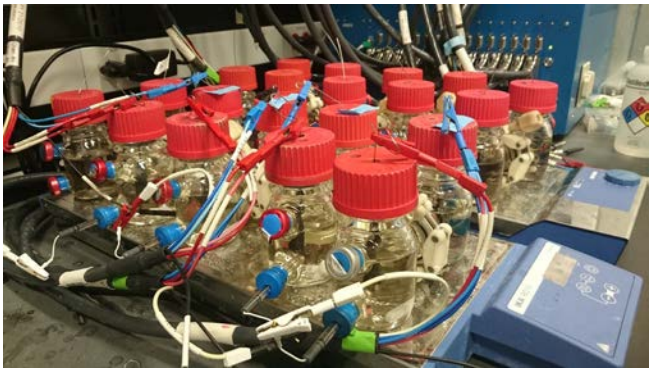

Figure 4. Laboratory set-up of electrochemical reactors prepared for long-term operation

PROGRAM STATUS

Tasks that included biomolecular and chemical monitoring and reporting of the electrochemical reactor performance with intermittent electricity supply are completed. The Stanford and NYSEARCH teams are examining how to fully develop a scalable and optimized electrochemical system that will maintain the performance of the microbes as seen during laboratory experimentation.

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Reducing Green House Gas Emissions

NGA NORTHEAST GAS ASSOCIATION
NYSEARCH

Technology Brief

Reducing Methane Emissions at Threaded Connections

Description: **A formal, scientific testing program to evaluate emissions from threaded connections in meter set assemblies.**

Status: **Testing of thread workmanship, sealant application, and applied torque is ongoing.**

BENEFITS

A formal, scientific testing program to evaluate currently used threaded fittings for potential of methane emissions and conformance to National Pipe Taper (NPT) specification will provide insight into actions that could be taken to reduce fugitive emissions in distribution systems. This program will provide a qualification of emissions that can be expected from various threaded connections. Such results are intended to aid in making decisions to achieve reductions in greenhouse gas emissions.

BACKGROUND

Along with the safety of transportation of pressurized gas, expectations have been set regarding methane emissions from all sources including those at very low levels that result in any methane accumulations. While the overall contribution to greenhouse gas (GHG) emissions from natural gas distribution systems is low (AGA reports <1% of produced natural gas from distribution), threaded connections from meter sets and M & R stations are shown in some reports to account for up to 50% of those distribution system emissions.

Best Practice (BP) 22 published by the California PUC asserts through its language that better quality pipe threads with tighter tolerances may be necessary to reduce GHG emissions. BP 22 anticipates potential revision of pipe fitting specifications, if necessary, for threaded connections with significant leaks. Alternatively, best practices could include comprehensive procedures for meter set assembly fabrication and repairs. These recommendations indicate that the utilities need to study, react, and potentially change specifications on threaded connections. If implemented, this would go over and above requirements in the current standard (ANSI B-1.20.1).

While it is believed that manufacturers meet industry standards, one measure of the precision of mating/matching of threaded connections comes with conformance and quality control checks using the NPT thread specification. One notion is that a more precise thread standard, the Aeronautical standard (ANPT – AS71051), could reduce the mismatch and improve the fit; therefore, potentially reducing leakage. (A precise thread taper could improve the seal when the thread flanks are compressed during the torquing process.)

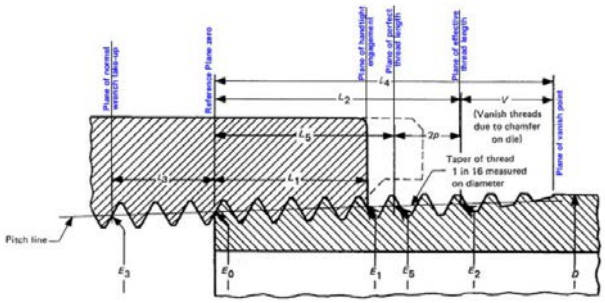

Figure 1: National Pipe Taper Threads

Thus, there is a need for a holistic investigation of the cause of emissions from threaded connections and the impacts, both positive and negative, of using a more precise taper standard on the thread. There are other potential causes such as damage and use/misuse of sealants.

TECHNICAL APPROACH

The overall objectives of the NYSEARCH program are to demonstrate the sealing performance of threaded connections, to understand the ability to reduce emissions, and to determine the impacts

of changing the thread specifications or finding alternatives such as sealants or other best practices to reduce fugitive emissions.

In Phase I, a project was completed which gathered preliminary data on the state of fittings currently being procured by the funding utilities and their conformance to the NPT thread specification. A major finding indicated that current fittings procured by the utilities (randomly sampled) have a lower success rate for meeting the NPT thread specification.

In Phase II, a rigorous test protocol was developed and implemented to perform comparative leak testing between NPT and ANPT thread standard joints. Specifically, the tests were designed to compare the performance of NPT thread specification joints against a combination of ANPT thread specification joints (nominal, only meeting one criterion, etc.). A statistical analysis was performed to determine the number of leaks after 30 years to test whether NPT and ANPT dimensional compliance was a factor for the probability of leaks over time. No failures were noted in of either test groups at the end of testing.

In Phase III, the test protocol was revised to extend and expand the leak testing to more severe environmental conditions and an increased cycle count to induce failures. An extended data set allows a statistical analysis to provide stronger conclusions. It also provides insights regarding the role that adherence to a specific thread specification ultimately plays in leakage rates for threaded connections. Similarly, the behavior of fittings is also being evaluated to understand the impact of "bad" fittings (i.e., out of spec fittings received from a manufacturer or reused fittings that may fall out of compliance) on the potential number of leaks developed over time.

In the most recent phase of the program, the contractor, Bruce Campbell Consulting is investigating additional factors that could influence emissions at the thread: 1) when applying thread sealant to potentially reduce emissions, what the risk is of the sealant dislodging and traveling to cause other clogs or issues, 2) testing different levels of torque when tightening the threaded connection to see whether any level raises risk of leakage, 3) examine whether quality control and workmanship impacts emissions, and 4) when applying thread sealant on the internal and external threads, does it reduce the risk of leaks developing?

Figure 2: Sample threaded connection test configuration with different types of joints

PROGRAM STATUS

Phase III of the project is complete. Numerous connections including tees, nipples, valves, and elbows were tested. The statistical analysis showed that out of a population of 1 million joints with 95% confidence, both test groups NPT vs. ANPT fittings and NPT vs. OS fittings did not present any statistical difference in performance.
The work investigating additional factors is ongoing and initial results are showing that applied torque does influence the failure rate of threaded connections. Additional testing is underway to corroborate these initial findings.

Highlights

- A program to measure and evaluate the impact of thread specifications (NPT and ANPT) on the failure and leak rates of threaded connections.
- Project also investigating workmanship, sealant application method, and applied torque to determine if these factors influence leak rate.

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NGA NORTHEAST GAS ASSOCIATION
NYSEARCH

Technology Brief

Classification of Emissions at Regulator Stations

Description: A project to assess sources of emissions at LDC-owned Regulator Stations and to develop and validate a framework for classifying and then mitigating those emissions

Status: Following data collection from participating members and site visitation, the classification scheme was established and an emissions ranking tool completed. A new phase of work is ongoing to validate the emissions ranking tool.

BENEFITS

A method to consistently assess and standardize the prioritization and measurement of emissions can increase safety by enabling a practical approach for identifying even small methane emissions. The process could also identify large emitters. Reducing emissions improves the environment and demonstrates to gas customers how even the smallest source of emissions are important to eliminate.

BACKGROUND

Regulators and environmental organizations do not always agree with industry metrics on the magnitude of methane emissions from the transmission and distribution sectors despite extensive collaborative work to define 'emission factors'. It is generally agreed that for the distribution sector, while our emissions are a much smaller percentage than other sources, one of the biggest contributors comes from occasional venting and leaking at regulator stations.

With the current emission factor measurement methodology, it has been noted by those who have studied the process that it is difficult to accurately assess regulator stations due to a number of factors. They include: 1) range of sizes, 2) design, 3) geographic location, 4) valve type, 5) changing pressure and flow rates, and 6) procedures for venting.

TECHNICAL APPROACH

The objective is to develop a framework and quantitative methodology for classifying emissions at regulator stations. Our goal is to reduce variability in emissions estimates and /or properly classify regulators to prioritize for additional work to measure and mitigate emissions.

Three tasks were addressed through two contractors who are experts in gas control equipment and leak measurement. The three tasks were: 1) Regulator Station Inventory and Classification, 2) Confirmation of Emissions Measurement Technology, and 3) Field Test program.

For this first segment of work, it was agreed that the emissions of interest were those fugitive emissions that come from design or 'engineered' emissions during pressure reduction. The classification methodology was found to be difficult to turn into a quantification process and thus, was first evaluated as a way to better bin the equipment and prioritize where to make measurements.

Figure 1: typical station with multiple valves and pressure reduction equipment

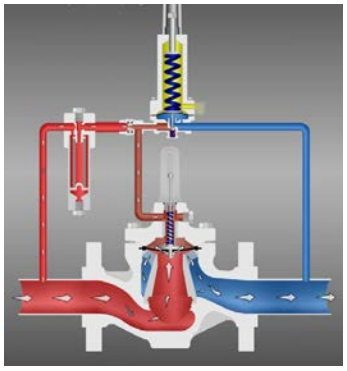

Figure 2: sample regulator design with pilot valve

PROGRAM STATUS

Following significant exchange with funders and Subject Matter Experts (SMEs), the classification framework was completed. For the very few sources of emissions under very specific conditions, the pilot-controlled valves that have intermittent or continuous bleed, had three factors that were analyzed: 1) volume of gas in the valve chamber, 2) valve travel and, 3) frequency of valve movement. Numerous factors were found to potentially play a small part in emissions estimates. They included: hardware, system operation, control, seasonal/environmental influences and whether the station handled industrial/power applications.

Four categories were defined: 1) Category A – no bleed to the atmosphere and extremely minimal risk of component leakage, 2) Category B – low pressure system application; minor releases of pilot control releases of gas associated with remote control or SCADA/RTUs, 3) Category C – intermittent moderate emissions that are associated with high pressure systems, and 4) Category D – continuous large emissions from high pressure systems. Emissions that were found for Class A and B were very minor and based on emissions from abnormal operating conditions such as leaking connections or failed components.

The contractors also delivered a qualitative ranking tool (spreadsheet) that they designed based on generic families of equipment where there were variables of interest based on the factors listed above. Using extensive control/pressure reduction experience and review of data from numerous sites supplied by NYSEARCH funders, the consultant developed the relative weighting ranking tool. The tool provides a relative number that combines assessments of several contributing factors to emissions. In addition, five sites that were assessed as potentially fitting into Categories C and D were visited to run through the classification process and to determine if quantitative emissions measurements could be made. Only some of those sites were expected to provide conditions adequate to measure emissions over the long term. [Many emissions are small and in a dynamic or fleeting state.] For some of the components that were found to be emitting gas, further work is necessary. Attaching different types of measurement devices to regulator station over a period of time requires participation and approval of personnel related to station design and maintenance.

NYSEARCH funders then considered a holistic measurement process to quantify emissions using the framework that resulted from this project. Multiple validation methods are being considered. The funders of the Phase II follow-on effort are now working on a validation test protocol with IES Engineering and their SMEs to ensure that the ranking tool represents a standard framework for field conditions (even though individual company customization is also anticipated).

Highlights

- Focused on very small sources of emissions from pressure reduction conditions
- Found very few sources of emissions and focused on those from high pressure systems with intermittent or continuous bleed
- Delivered to funders a relative ranking tool and several examples based on site verification

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NGA NORTHEAST GAS ASSOCIATION
NYSEARCH

Technology Brief

Standardization of Surface Expression (SE) Measurements for Methane Emissions Validation

Description: **A technology optimization and test program to enable standardized use of a stationary measurement tool and process to validate methane emissions measurements.**

Status: **Two phases of work have been completed and field testing has validated accuracy and optimized process. The project is moving to an activity to create a national standard and funding members can use the results of this work to independently verify measurements of methane emissions.**

BENEFITS

Prioritization of non-hazardous leaks (sometimes referred to as 'Type 3' leaks) based on their methane emissions or flow rates can further advance techniques for quantifying methane emissions from the LDC gas infrastructure. Methane emissions information supports the goal of achieving the highest standard in safety while practically addressing rehabilitation of aging infrastructure in a manner that also considers greenhouse gas emissions. In this project, a tool that is widely known to help validate other methane emissions measurements (whether through mobile, walking or airborne surveys) can be advanced to reduce uncertainty and improve precision on calculating the contribution of non-hazardous leaks to overall methane emissions. Having an accurate confirmatory tool that is standardized for all users and that address gas industry emissions can support a collective push to prioritize the most significant causes of methane emissions. Further, with confidence in a process that is fully quantified and standardized, decisions to address sources of emissions can be supported by strong sources of data.

BACKGROUND

In an effort to reduce methane emissions, numerous entities from the gas industry and academia are investigating how to quantify methane emissions rates and the best methods for prioritizing repair that factors in safety and contribution to greenhouse gas emissions.

While no leak is desirable, by definition, a non-hazardous leak takes less of a safety priority than a hazardous leak but collectively, non-hazardous or "Type 3" leaks contribute to the greenhouse gas /carbon footprint. As such, any leak repair program that targets repair of non-hazardous leaks can serve to reduce methane emissions. In 2019, NYSEARCH completed a program entitled "Technology Evaluation and Test Program for Quantifying Methane Emissions related to Non-Hazardous Leaks". The first three phases of this program are described in a February 2018 issue of Pipeline & Gas Journal. Further, in 2018, NYSEARCH, with cofunding from PHMSA/DOT, embarked on the Emissions Quantification Validation Process project. Within that project, the Surface Expression (SE) Measurement technique was determined to be one of the most reliable benchmarking tools for comparison of measured emissions by various third parties to actual metered emissions. However, using a statistically significant database from over (300) validated leaks, it was determined that the SE Measurement equipment and process could be further advanced and standardized in its use.

TECHNICAL APPROACH

The objective of the program is to improve and standardize the SE Measurement techniques for use in measuring gas pipeline emissions.

In the first phase, numerous data sets were consulted, and additional laboratory and field testing were performed to identify the sources of

error in the stationary SE measurement equipment and process. The contractor, GHD Services Inc., in consultation with the NYSEARCH funders and the project manager fully analyzed the process. GHD was able to deconstruct the system and isolate sources of error as components were added back into the system. (See Figure 1.) Based on various lab and field tests, GHD was able to confirm that uncertainty measured at over 27%

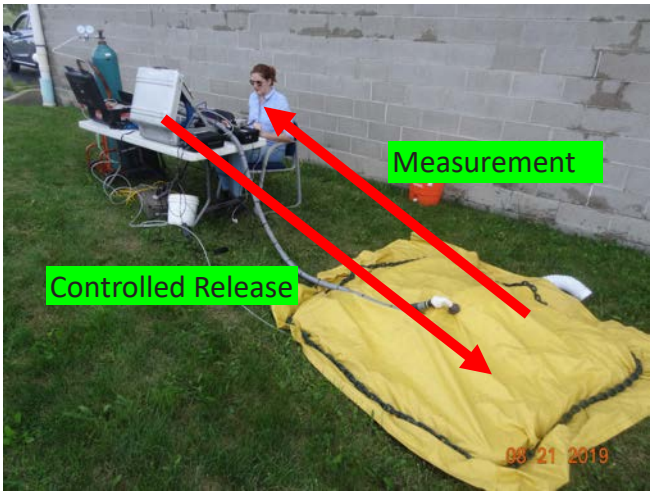

Figure 1: Scene from lab/controlled testing

Figure 2: Scene from Phase II field testing of SE Measurement Technique

prior to the work in this Project (assuming 80% confidence interval) could be reduced to less than 10%. In addition to use of a Design of Experiment (DOE) process, the project team identified critical processes that impacted the measurement and then developed hardware improvements to optimize the measurement process. A repeatable field test procedure was then employed. In some field tests, native leaks were measured. In others, both a native leak and an additive marker gas were measured. A variety of leak sites with various dispersion profiles and layouts or geometric configurations were tested. (See Figures 2 & 3). In Phase II, field testing and further data analysis allowed optimization of the measurement process and addressed unique widely dispersed leaks that could cover multiple grid measurements.

PROGRAM STATUS

In addition to reducing the overall uncertainty of the SE measurement system, GHD identified means for reducing under-estimation of methane flow rates using a unique calibration process.

Field testing in Phase II is complete. We have learned that the SE measurement process can be adapted to any migration pattern or field condition. Our testing has also validated the improved accuracy through this refined process. Results warrant an activity to work with a standards organization to codify this process in an accepted national standard. Work on that is approved and pending.


Figure 3: Closeup of one grid leak testing using SE Technique

Highlights

- A DOE that collected data from multiple sites supports the use and standardization of this stationary measurement process for benchmarking.
- The work has confirmed that this process is accurate and can serve as a reference confirmation for 3rd party measurements of GHG emissions.

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Improved Installation Maintenance & Repair

HoloLens based Training Library

Description: **Develop a shared asset library of digital content to be accessed while developing training programs for digital learning or use with XR (Mixed, Augmented, and Virtual Reality) technologies.**

Status: **Asset library is under development.**

BENEFITS

The belief is that XR technologies, such as the Microsoft HoloLens, will be instrumental in closing the skill gap that is responsible for the shortage of skilled workers. The NYSEARCH Training Asset Library would help accelerate the adoption of these technologies through cost savings, resource access, and best practices discovery. In addition, short-term benefits of this library include faster training development, reducing cost and instructor/SME resources, standardizing content, increasing throughput, and mobile-friendly access. The longer-term benefits include improving training flexibility to meet the needs of the gas operator training, satisfying common training needs across the gas industry, and improving knowledge sharing and synergies among members.

BACKGROUND

The gas industry is experiencing a tremendous amount of growth and construction activity to expand its footprint and to replace aging infrastructure. Simultaneously, a large number of retirements and turn-over from the COVID19 pandemic have expanded the need to bring in a new, younger workforce that needs a high degree of training, certification by various entities, and operator qualification. This results in an extensive and urgent need for expanding gas operator training programs and a need to adopt new innovative training methods.

Today, to rise to a fully rated, high level operator, training must be gained in the classroom and in the field. Rarely are gas industry field conditions able to be simulated without actual participation in field activities. The motivation for an Augmented Reality (AR)/HoloLens test program was and remains the ability to bring 3D reality for various tasks to gas company training programs. This can accelerate the ability of the trainee to experience the conditions that are required for that task and to make the process for gaining knowledge more accurate and efficient. Microsoft released the first-generation HoloLens device in 2016 and advertised the ability for users in personal or commercial situations to develop their own applications.

Figure 1: : Microsoft HoloLens

NYSEARCH evaluated and reported on the possibilities of using the HoloLens to address one or more gas training tasks in a hands-free, heads-up fashion using AR. Pilot testing with the HoloLens 1 was completed and analyzed, and in February 2018 NYSEARCH entered development where AR contractors were identified to create a custom training application the consortium.

The initial contractor, Tsunami/Inhance Digital, delivered a gas training application in May 2019 that met the specifics of the work scope. A new contractor, CraneMorley, Inc. was identified for Phase II and they developed a custom leak investigation application and a Microsoft Dynamics 365

Guides application of a complete Meter Set Assembly build procedure.

Phase III was recently completed where CraneMorley created customized gas operations procedures using the Microsoft HoloLens 2 for individual utilities for various applications including meter set assembly, a bolt tee removal procedure, a valve changer tool, and PE pipe fusion. In addition to building a customized Microsoft Dynamics 365 Guides, CraneMorley has helped to train each utility's core staff with this new technology.

During Phase III work, CraneMorley observed a common need for many training topics to be shared across the gas distribution sector. As new media is developed, much of it meets the same requirements for more than one LDC and yet companies tend towards independent developments. The motivation for this asset library is to centralize media content, identify common training needs, and develop these trainings to share across member companies.

TECHNICAL APPROACH

The overall objective of the project is to develop a shared asset library of digital training content for funders to access while developing training programs for digital learning or use with XR (Mixed, Augmented, and Virtual Reality) technologies.

The library would give access to a myriad of resources and assets that can be used as-is or re-purposed to support internal training and on-the-job performance. These resources include video, photography, eLearning modules, job aids, Dynamics 365 Guides modules, and more. The developed assets will be able to not only download these assets but upload them as well. Over time, the NYSEARCH Training Asset Library could become a resource from which everyone can benefit.

The library will have plenty of developed assets and will be a customized production of content (i.e. videos, Dynamics 365 Guides Modules, 3D models, eLearning modules) under the direction of the project roundtable. The approach and execution will be directed by a roundtable comprised of NYSEARCH consortium members who champion

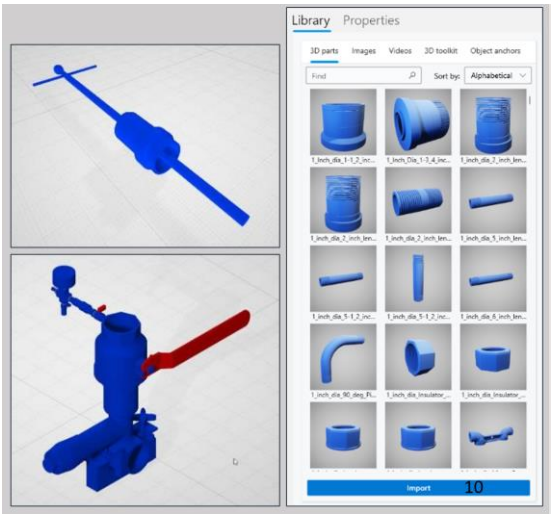

Figure 2: Example of a HoloLens Digital Library

the use inside their respective organizations and will facilitate future contributions by their individual utilities for the benefit of the library.

PROGRAM STATUS

Cultivation of digital assets is in progress. The success of this project depends on both the quantity and quality of digital content we can gather and create to build the asset library. A roundtable of NYSEARCH funding members has been useful. Monthly meetings are occurring to discuss training areas where digital content would be most effective and selecting digital content to be cultivated from the funders or created as new content.

Highlights

- Building on previous project where NYSEARCH successfully developed several customized Microsoft Dynamics 365 Guides for gas operations training.
- Asset library is in development.

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NGA NORTHEAST GAS ASSOCIATION
NYSEARCH

Technology Brief

Automated Inspection Pass/Fail Tool Using NDE on PE Pipe Butt Fusion Joints

Description: A technology automation to compare critical flaw characteristics in PE pipe joint based on established acceptance criteria
Status: NDE automation using artificial intelligence is being developed to provide pass/fall inspection results based on integrity acceptance criteria of PE pipe butt fusion joints

BENEFITS

Automation of a Nondestructive Evaluation (NDE) processes that compare joint interrogation results with known acceptance criteria would provide insight to a non-expert NDE inspector deciding to pass or fail a field fabricated joint. An automated algorithm provides a simple pass/fail indication from NDE results that visually indicate the joint integrity (red – probability of failure and green – within acceptable limits), see Figure 1.

Figure 1: Automated NDE inspection results display indicating pass/fail.

BACKGROUND

Currently, inspection of PE pipe butt fusion joints is performed by a visual assessment of the external side of the rolled back beads at the fusion. ASTM F2620 provides guidance for visual inspection of butt fusions based on the observation of the resulting joint configuration. The final acceptance of this assumption is the visual appearance of melt fusion beads.

Automated NDE methods have been developed in other industries that apply comparisons of known critical flaw characteristics and acceptance criteria to the inspected results of the butt fusion joint. Some of these NDE methods are available to the gas industry today, however they require a high level of certified NDE expertise to be performed and interpreted for the NDE result to be interpreted properly.

Previous NYSEARCH projects were successful in obtaining critical flaw characteristics and acceptance criteria for PE pipe butt fusion joints. Prior extensive destructive testing and analysis of specifically designed flaws that were placed in PE pipe joint samples have provided the basis for the critical flaw characteristics and acceptance criteria for this and other projects.

Automated techniques allow for trained non-NDE LDC personnel to collect NDE interrogation data and then have a comparative algorithm to: 1) evaluate those results with critical flaw characteristics, and, 2) provide a final joint acceptance recommendation. Use of these techniques by trained non-NDE personnel would provide a broader application for LDC operations.

Eclipse Scientific is an accomplished and experience NDE developer and provider. They are active in providing NDE applications across a wide range of industries. They are also involved with national standards and certification development (ASTM, ASNT, ASME). Also, Eclipse Scientific has experience developing NDE artificial intelligence pass/fail hardware and software for other industries.

Their experience in performing research and development on new NDE applications attracted NYSEARCH to work with Eclipse Scientific in developing an automated approach for NDE application of PE pipe butt fusion joints for the gas distribution industry.

TECHNICAL APPROACH

The objective is to develop an automated NDE Pass/Fail tool to inspect PE pipe butt fusion joints performed by properly trained but non-NDE expert LDC personnel. Eclipse Scientific is basing their development of the automation algorithms on the critical flaw characteristics and acceptance criteria information provided by NYSEARCH which is essential in setting bounds for the pass/fail interpretation.

NDE development is based on established fundamentals of Phased Array Ultrasonics (PAUT), see Figure 2. Interpretive algorithms are using PAUT NDE results for the initial technique in automation comparisons. However, the algorithms are not dependent on PAUT as one specific technology. As new and improving NDE techniques are developed, algorithms provide more in-depth insights to the butt fusion joint flaw detection. Also, the algorithm can be modified to incorporate the advanced NDE technique; thus, continually improving overall interrogation results.

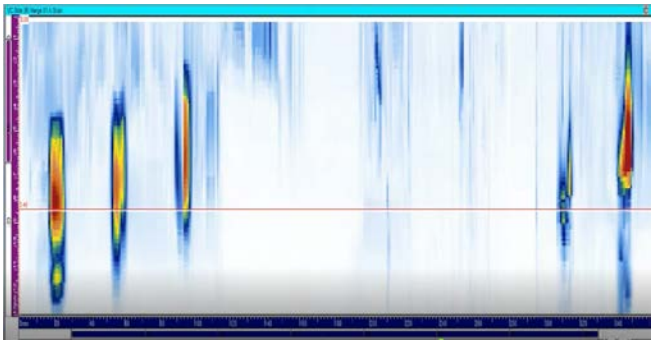

Figure 2: Typical initial results from PAUT NDE detecting anomalies within a PE pipe joint

PROGRAM STATUS

Eclipse Scientific has developed the NDE platform for inspection on PE pipe. Inspection techniques use PAUT pitch-catch type signaling through transducers that send ultrasonic energy through the PE pipe wall and measure differential time to reflect off anomalies within the material volume of the PE pipe and the insider diameter of the PE pipe wall, see Figure 3.

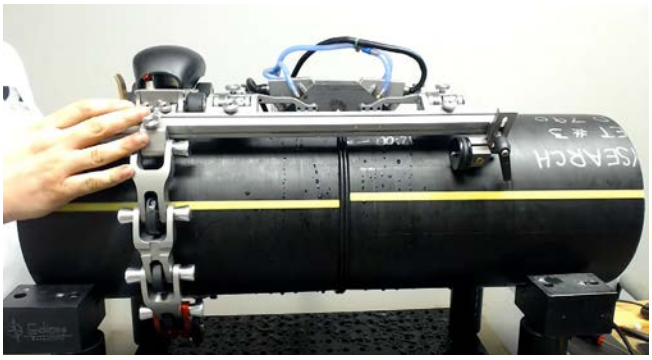

Figure 3: Typical application configuration of PAUT NDE inspection of a PE pipe joint

Currently, the automated NDE system is being exposed to defects embedded in sample PE pipe joints samples to develop the comparative bases for pass/fail decisions.

A demonstration of the advances in Phase II is being scheduled. In addition, trials in gas company laboratories and actual field trials are being scheduled.

For more information contact:
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Highlights

- NDE inspections allow use of PAUT with minimal NDE experience
- Automation provides a comparison between critical defect characteristics and established acceptance criteria.
- Results of the inspection shown on tool display with a simple red/green indication of the probability of joint failure

NDE Tool for Evaluation of Electrofusion Fittings

Description: Identify, investigate and select a non-destructive evaluation (NDE) method to evaluate electrofusion (EF) fittings on polyethelene (PE) pipe joints.

Status: Feasibility of NDE Xray technique proven and endorsed by project funders. Field tests pending.

BENEFITS

The benefit of performing Non-Destructive Evaluation (NDE) on polyethelene (PE) pipe ElectroFusion (EF) joints is to confirm the internal PE pipe ends and fitting are positioned correctly and to ensure no obvious debris has been embedded within the final joint configuration during the fusion process.

BACKGROUND

Inspecting PE EF pipe joints is an important quality control check to confirm that the fusion between the pipe and EF fitting has been properly formed and to ensure its long term performance. Currently, the extent of inspection is limited to visual observation on the final exterior joint surface due to the internal configuration of the EF joint being concealed. If each step in the preparation of the PE pipe and EF fitting could be confirmed through direct observation, then the we would be able to fully assess a final EF joint's internal configuration. This would provide higher confidence in the quality of the EF joint.

There are some NDE methods available to look beyond the outer surfaces of PE pipe electrofusions. Various NDE methods provide high granularity inspection of the joined material between the PE pipe and fitting. However, many of these NDE techniques, such as phased array, ultrasonics, microwave, and Terahertz, require highly trained and experienced NDE personnel to perform the interrogation and interpret the results.

A method of NDE inspection is needed that will enable a non-NDE expert to see within the EF joint to: 1) observe the general configuration within the EF joint, 2) confirm that the PE pipe ends and the fitting were positioned correctly and, 3) show that no obvious foreign objects have been embedded within the final joint configuration during the fusion process.

An NDE method is needed such that it can convey the results of inspection in a practical and easily interpretable way to non-NDE experts all the while still revealing the conditions within the EF joint(s). These non-NDE experts could be experienced PE technicians and/or quality inspectors who would recognize and interpret NDE inspection results.

Figure 1: 2 Inch PE Pipe EF Joint

TECHNICAL APPROACH

The objective of the project is to identify and evaluate non-destructive (NDE) tools and instruments capable of enhanced visual inspection of electrofusion (EF) PE pipe joint interiors for

assessing general assembly configuration and final fabrication.

A NYSEARCH working group developed field application requirements for the application of x-ray inspection to be performed, which included safety protocol, training pre-requisites, and environmental concerns. In parallel, various PE EF pipe joints samples were made with specific anomalies representing typical defects that may be found within a EF joint. Samples of these typical defects embedded in an PE EF pipe joints were used to test the digital x-ray NDE instrument and provide images of the field procedures.

The working group also engaged a digital x-ray expert to aid in the development of the field application procedure. The digital x-ray expert is providing the bounding application conditions to develop an appropriate training process and operational procedure for the non-NDE expert to follow when performing inspections. Sufficient practical details on the x-ray field set up, a clear investigation process, and interpretation are to be provided to the non-NDE expert while performing an PE EF joint internal examination. Three (3) field tests at funder training facilities and/or field sites are being conducted by company crews to test and prove the field procedures for practical use and application.

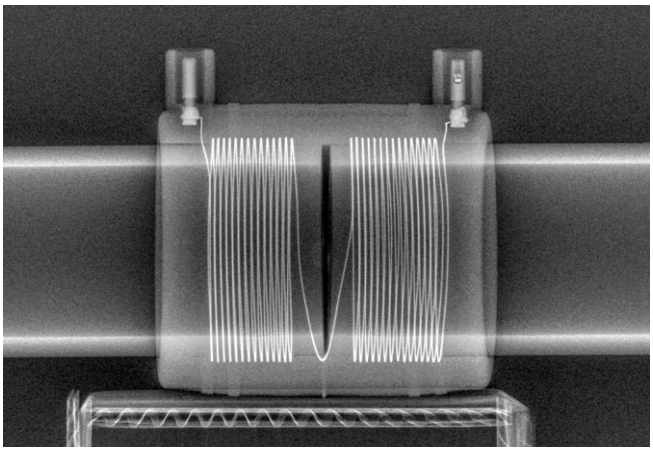

Figure 2: Internal xray view of 2 Inch PE Pipe EF Joint with symmetry of heating wire uniform and melt zones clearly indicated

The final planned task is to review all field tests for lessons learned and improvements. Also, a formal application procedure is being written along with training materials that summarize the NDE objectives developed by the working group and Subject Matter Experts (SMEs). Additionally, a report on initial x-ray images of specific PE EF joints is being completed and reviewed to determine the effectiveness of an x-ray NDE approach.

Also, an NDE expert is being engaged to develop field training and procedures for the effective use of the digital x-ray NDE method to be performed by non-expert NDE PE technicians and quality control personnel.

PROGRAM STATUS

The project working group developed a detailed test program. The new NDE x-ray tool was utilized to inspect two (2) inch EF HD/MDPE joint samples and the results have been reviewed favorably. Currently, field test applications and training are being developed and field test NDE EF PE joint procedures are under development.

Highlights

- NDE x-ray acceptance criteria imagery provides pass/fail interrogation results
- Field testing planned for mid-2023

For more information contact:
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Development of Plastic Pipe Fusion Workmanship Acceptance Criteria & Visual Acceptance Tool – Phase I & II

Description: **Create a visual NDE tool for field inspection of plastic fusion joints to provide a uniform basis for joint interrogation decisions leading to pass/fail decisions**

Status: **A Visual Field Guide has been created with illustrations of acceptable and rejectable visual indications for plastic pipe fusions**

BENEFITS

A successful outcome would provide operators with a standardized process for visual nondestructive examination (NDE) that could be promoted to regulators as a consistent approach to increased safety and optimize work practices. If the process and associated tools were to provide consistency and backed by the operating companies in NYS, customers would benefit with enhanced safety and work prioritization.

BACKGROUND

The New York Public Service Commission (PSC) issued an Order requiring excavation and retrieval of plastic pipe butt fusion joints in certain conditions for accepting and qualifying a plastic pipe fused joint. That Order requires destructive testing to validate the efficacy of those retrieved joints. This regulatory requirement, that is currently deemed necessary by the PSC to address previous concerns, makes it important for NY gas companies to work quickly for both interim and long term solutions on accurate and proper in-situ qualification of fused PE joints so that safety measures and priorities are not compromised.

The Order also addresses the need for study and implementation of workforce acceptance practices that include enhancements to visual inspections of plastic pipe fusions. Thus, the New York Advisory Committee (NYAC) of NGA has worked to identify their common needs associated with visual inspection of fused PE joints. In parallel, NYSEARCH has several projects that are medium and longer term (with years of background work that took longer than expected) to develop an NDE tool for volumetric assessment of butt fused PE joints as well as to formalize methods for validating the usefulness and accuracy of other commercial or pre-commercial joint inspection tools as they are brought forward by commercial providers. Currently, there are four (4) active advanced NDE projects involved in volumetric joint inspection techniques. In contrast, this project focuses specifically on visual inspection methods.

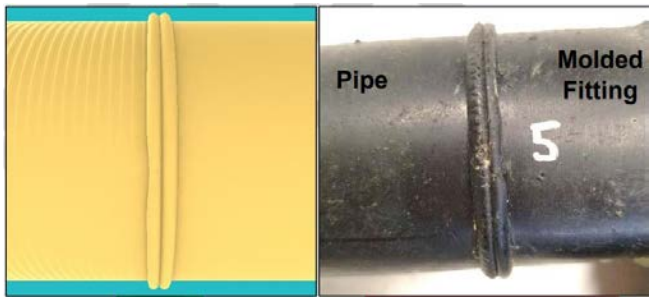

Figure 1: Example from Field Guide of an Illustration and photo of Acceptable and Unacceptable Non-Uniform butt fusion bead roll back

TECHNICAL APPROACH

The objective of the project is to use existing data to build consensus on a new approach for visual inspection of fused PE joints that enables a consistent and statistically-based sampling process.

In this project, GTI worked with Subject Matter Experts (SMEs) to gather pre-existing joint fusion and failure information, using primarily photo images. Then, they formulated a database and completed a gap analysis of the various QA/QC inspection practices of the NY companies. Subsequently, GTI reviewed the findings and made

recommendations to assess current practices and present options for more consistent visual inspection practices that was reviewed by the funders.

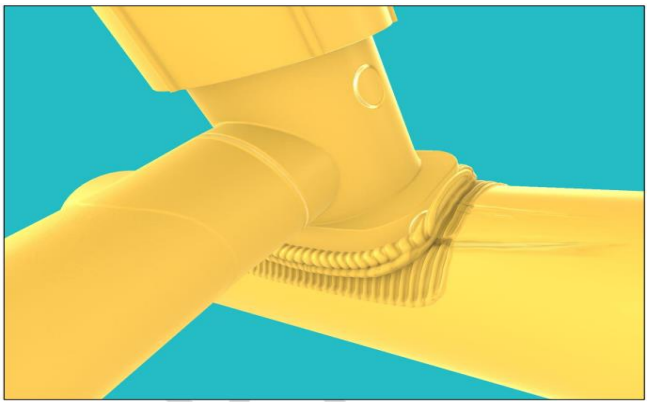

Figure 2: A Visual Field Guide example of Unacceptable gouges on pipe surface when fusing a service tee

Phase I was organized into three tasks. In the first task, using information provided by NY SMEs through NYAC and other designees, current visual inspection practices were reviewed with SMEs and process analysis was done. In Task 2, existing images were collected and used to assess workmanship acceptance (pass/fail decisions) and current procedures that lead to follow-up destructive testing. Assessment information and test results were combined into a database to be set up to capture historic information as well as aid future data analysis and potentially machine learning. In the final task, Task 3, GTI performed a gap analysis on QA/QC inspection practices.

In Phase II, SMEs reviewed GTI's recommendations to reach consensus on the enhanced visual inspection process. The Phase I and Phase II deliverables were the database and a Final Report.

PROGRAM STATUS

The gap analysis between gas companies' fusion procedures and visual inspection criteria was completed. The project resulted in development of a comprehensive visual guide to enhance the ASTM 2620 inspection acceptance criteria. This comprehensive approach using actual photographs and computer-generated illustrations provides a reference for pass/ fail conditions to avail consistent inspection techniques.

The Final Report and all deliverables are near complete.

Figure 3: A Visual Field Guide example of an Illustration of an Acceptable and Unacceptable mitered butt fusion alignment

Highlights

- The Visual Field Guide provides a consistent inspection basis for field inspector across all gas companies.
- The Visual Field Guide provides a basis for the field inspector to make visual decisions to pass or fail a plastic fusion joint.
- Inconclusive inspection results based on this Visual Field Guide would provide the field inspector to call for more extensive NDE techniques.

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Innovations for Pipeline Integrity Direct and Remote Assessment

Visual Inspection of Two (2) Inch Plastic Pipe

Description: A program to develop a new advanced platform that carries a camera, which is capable of navigating two (2) inch polyethelene pipelines and associated features to detect degradation and delamination.

Status: Feasibility proven. Detailed design to be finalized.

BENEFITS

The development of new non-destructive evaluation (NDE) technologies to inspect natural gas pipelines has been a focus of the NYSEARCH consortium, and its members have invested considerable resources in research, development, and demonstration activities of these technologies to provide pipeline operators with a plethora of solutions to efficiently and effectively inspect natural gas pipelines. The benefit of this project is that it provides a new platform capable of visually inspecting two (2) inch polyethelene (PE) pipe internally to identify internal defects, including potential degradation and delamination, which has been documented to occur in PE pipe installed between 1978 and 1999 that has been subjected to elevated temperature conditions such as those experienced in the south and the desert southwest or the United States. This In-Line Inspection (ILI) tool will allow internal inspection of two (2) inch PE pipe over long distances and under live conditions. This new design will allow the systematic inspection of PE pipes, sometimes in service for over (50) years and provide detailed information over longer inspection distances than what is presently possible. This additional information will provide predictive analytics on fusions on PE pipe as well as straight sections to aid asset management decisions and to expand the proactive pipeline safety management culture that the gas industry wants to advance. Increased range and simplicity will avail more inspections in a range of PE pipes.

BACKGROUND

Medium and high density PE pipe, MDPE and HDPE respectively, manufactured between 1979 and 1997, and installed in natural gas distribution systems between 1978 and 1999, was flagged in PHMSA's March 2012 Advisory Bulletin as being a potential pipeline integrity risk because it was found to degrade when subjected to elevated temperatures such as those experienced in desert-like environments in the southwestern United States, namely Arizona and Nevada.

In November 2013 Performance Pipe, a division of Chevron Phillips Chemical Company and the manufacturer of the pipe, published a report reporting on the findings of their testing and engineering analysis and this report recommended that that "*operators in the highest temperature regions, such as the desert southwest and southern most regions of the United States may want to inspect and sample a broader portion of their system in conjunction with the risk ranking*."

Figure 1: Two (2) Inch PE Pipe Test Layout

A small number of efforts have tried to identify technologies that would be able to inspect from the inside or the outside of the pipe with very limited success. After investigating acoustic and ultrasonic technologies (GE USM-Go+ system), both were tried, and proven to be impractical for the two (2)

inch PE pipe inspection application. Camera technologies were also tried for internal use, but were abandoned as they provided very limited operational range in addition to facing other operational issues, such as causing substantial damage to the internal surface of the PE pipe.

Therefore, the industry is in need of a tool that will allow live insertion of a sensing element and a camera to be able to detect degradation and delamination in MDPE and HDPE, which is able to travel relatively long distances and negotiate the obstacles encountered in the typical distribution network, such as bends and tees. Ideally, the new tool would be capable of operating without a tether and be controlled by the operator wirelessly while having enough power to provide for a long range. Over the past 15 years, a system with such capabilities, Explorer, was successfully developed by NYSEARCH/NGA with co-funding from PHMSA for metallic transmission natural gas pipelines. Through a successful feasibility study conducted in 2022 for PE pipe , a new design for a robotics platform with a sensory system was selected for further development and eventual commercialization for pipe sizes of 4" and greater, while a camera-only system was selected for 2-inch PE pipes.

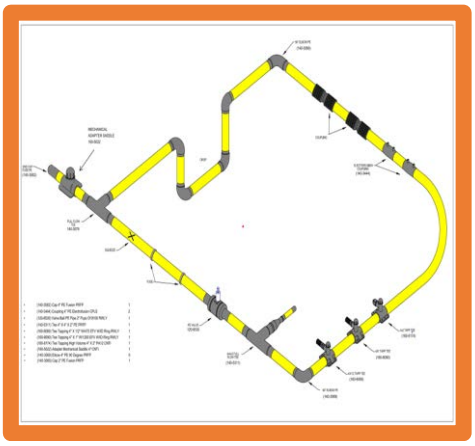

Figure 2: Two (2) Inch PE Pipe Layout

TECHNICAL APPROACH

This project is focused on utilizing the results from the aforementioned study, which identified robotic technologies equipped with sensors capable of detecting degradation and delamination in non-conforming Driscopipe ®8000 (NCDP) through live in-line field inspection, to specifically focus on inspection of two (2) inch MDPE and HDPE. The objective of this project is to design, build, and lab test a new platform concept for the visual inspection of two (2) inch plastic pipe under live conditions and focusing on long-range operation. A systematic study of sensory technologies for the detection of defects in 2" pipes was carried out and it was determined than no non-destructive evaluation technologies exist that could fit in the extrememly limited physical space available on such a small system; as a result the only sensory technology onboard will be a camera. This project has taken the selected concept from the precursory project, mentioned above, and performed a detailed design and development of a lab test setup. Design of a prototype engineering system has been completed that includes a tether for stabilization, speed control, and retrieval capability, including an on-board battery. The next steps are to finalize the design, and begin manufacturing components and assemble the engineering prototype for system testing and baseline performance evaluation. Once testing is complete and baselines are set, funders will review and move forward with commercial prototype building and field testing. Additional phases towards commercialization will follow.

PROGRAM STATUS

This project has successfully developed and proven a new concept for an advanced visual inspection system for two (2) inch MDPE and HDPE pipes that could enhance the safety and operational efficiencies of the natural gas distribution network. Additional phases are needed to design, test, and commercialize the technology for the benefit of the natural gas industry and the public.

Highlights

- Successfully developed a concept for a new visual inspection plantform for 2-inch PE pipe.
- Early-stage test results show commercialization feasibility.

For more information contact:
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Feasibility Study for a Robotic Platform and Suite of Sensors to Identify Degradation in Non-Conforming Driscopipe® 8000

Description: To develop a new cutting-edge robotics platform and array of sensors capable of navigating 2" and larger polyethelene pipelines and associated features to detect degradation and delamination, and other defects.

Status: Feasibility proven. Final report issued December 2022.

BENEFITS

With PHMSA's increased focus on integrity management, the NYSEARCH consortium has invested considerable resources in the development of new non-destructive evaluation (NDE) technology to provide pipeline operators with solutions to efficiently and effectively inspect natural gas pipelines. The benefit of this project is that it provides a new cutting-edge robotics platform and an array of non-destructive evaluation sensors capable of internally inspecting polyethelene pipe, as small as four (4) inches in diameter, to detect internal and external defects, including the potential degradation and delamination in non-conforming Driscopipe®8000 (NCDP) highlighted in PHMSA's March 2012 Advisory Bulletin. This in-line inspection (ILI) tool will allow the inspection of NCDP pipes and other PE pipes from the inside over long distances and under live conditions. Such a system will allow the systematic inspection of potentially compromised pipes and the detection of cracking and delamination before they result in gas leaks and potentially catastrophic failure.

BACKGROUND

Driscopipe® is a type of high density polyethylene plastic pipe used in the natural gas distribution system since the 1960s. Driscopipe® type 8000 pipe was produced from late 1979 through 1997 and was available in sizes from ¼" to 8" in diameter. In November 2013 Performance Pipe, a division of Chevron Phillips Chemical Company and the manufacturer of the pipe, published a report on the findings from an engineering analysis and tests conducted to identify the source of the problem.

The report recommended that "*operators in the highest temperature regions, such as the desert southwest and southern most regions of the United States may want to inspect and sample a broader portion of their system in conjunction with the risk ranking*." To the naked eye, the degraded pipe displays delamination or peeling on the outer surface and a crumbling appearance with many cracks on the inner surface of the pipe. (Figure 1)

Figure 1: Sample of Degraded Driscopipe® 8000

With the life of PE pipe sometimes exceeding (50) years for some inventories, information is needed to provide predictive analytics on fusions on PE pipe as well as straight sections to aid asset management decisions and to expand the proactive pipeline safety management culture that the gas industry wants to advance.

A number of limited efforts have been carried out to identify technologies that would be able to inspect from the inside or the outside of the pipe with very limited success. Acoustic technologies were tried for inspection from the outside of the pipe however, it requires excavating and exposing the pipe, which is not practical, if long segments of the network are to be inspected. When tried from the inside of the pipe, the need of a liquid coolant rendered the ultrasonics-based system impossible to use under live conditions. Camera technologies were also tried for internal use but operational range was limited in addition to facing other operational

issues. The industry is therefore in need of a tool that will allow insertion of a sensing element, able to detect degradation and delamination in Driscopipe® 8000, in a live distribution main able to travel long distances and

SYSTEM CHARACTERISTICS		IMPORTANCE
Pipe Material	HDPE	
	MDPE	
Pipe Diameter SDR 11	1"	
	1.25"	
	2"	
	4"	
	6"	
	8"	
Operating Pressure	60psi	
	124 psi	
Launching	Vertical Saddle	
	Angled Saddle	
Live inspection		
Obstacles Negotiation	Vertical Segments	
	Inclined Segments	
	Bends	
	Tees	
	Reducers - Stiffeners	
	Fusion joints	
	Valves	

Figure 2: Partial List of Initial Requirements

negotiate the obstacles encountered in the typical distribution network, such as bends and tees. It should be able to operate without a tether and be controlled by the operator wirelessly while having enough power to provide for a long range. A system with such capabilities was successfully developed, by NYSEARCH/NGA with cofunding from PHMSA, over the last 15 years for metallic transmission natural gas pipelines.

TECHNICAL APPROACH

This project focused on carrying out a feasibility study to identify robotic technologies equipped with sensors capable of detecting degradation and delamination in non-conforming Driscopipe ®8000 (NCDP) through live in-line field inspection. A systematic study of sensory technologies was carried out to identify the best technology in parallel with an effort to identify the best platform on which to integrate the sensor.

The objectives of this project were to: 1) develop appropriate specifications for an in-line inspection system for NCDP pipes (consisting of a sensory system and a robotic platform) that meet industry and other stakeholders needs, 2) identify and evaluate state-of-the-art sensing system(s) for detecting degradation and delamination in NCDR pipes, and 3) identify and evaluate robotic platforms able to carry such sensing systems inside natural gas plastic pipes.

Established technologies such as phase array ultrasonics, as well as emerging technologies in the field of NDE of plastic pipes, such as Terahertz and microwave, were considered and evaluated. A parallel study was conducted to identify the best robotic system able to carry such a suite of sensors. The study investigated a new design for a robotics system that would allow it to be launched, operated, and retrieved under live conditions and travel in natural gas plastic pipes over relatively long distances without a tether attached.

This work was conducted by a team consisting of NYSEARCH, Invodane Engineering (IE), of Toronto, Ontario, Canada, the robotics platform developer; and the Center for Nondestructive Evaluation (CNDE) at Iowa State University, the sensor system developer.

PROGRAM STATUS

This project has successfully developed concepts for advanced inspection systems for 4" and larger PE pipes that would enhance the safety and operational efficiencies of the natural gas distribution network. Additional phases are needed to design, test, and commercialize the technology for the benefit of the natural gas industry and the public.

Highlights

- Successfully developed concepts for advanced inspection systems for 4" and larger PE pipes.
- Developed systems that could enhance the safety and operational efficiencies of the natural gas distribution network.

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NGA NORTHEAST GAS ASSOCIATION
NYSEARCH

Technology Brief

Explorer Wireless Range Extender

Description: Develop technology(ies) to extend the range of the wireless communication of the Explorer series of robots to improve efficiency and productivity of inspections of unpiggable pipelines.

Status: Detailed design complete. Project moving to field testing and initial commercialization.

BENEFITS

Increasing the range of the Explorer series of robots has been an early target of the NYSEARCH consortium. Having developed a full range of Explorer platforms, having developed a suite of sensors able to detect corrosion defects, cracks, and mechanical damage, and having developed a system to provide additional power to the robot via energy harvesting methods, in recent years, we have focused our efforts on extending the range of the wireless communication system used on the robots. This is the last known barrier to long range operations, significantly higher operational efficiencies, reduced inspection cost, and lower risk inspections.

BACKGROUND

A Phase I project was approved by NYSEARCH members in June 2021 to initiate the effort to develop the technology(ies) that will allow the extension of the wireless communication range of the Explorer series of robots. Work was focused on carrying out a feasibility study to identify concepts for the mechanical, electrical, and communications subsystems.

A final report presenting the results of this effort was issued in February 2022. It details a concept based on a modified Explorer drive module to which deployable antennas could be attached. These antennas are to be deployed on the pipeline wall once wireless signal power and bandwidth have dropped significantly, thus re-establishing proper communication with the robot and allowing the robot to travel further.

A preliminary mechanical design of these deployable antennas and the system to deploy them and retrieve them was carried out. A proposed electrical hardware concept was also created to assist in lab testing of the various options in Invodane's radio frequency (RF) signal test loop to compare new communication network devices and protocols that have recently emerged commercially and which provide longer wireless signal ranges (see Figure 1).

Four potential electrical hardware options were studied extensively with two of them finally deemed the most promising. The combination of the two selected hardware options with the deployable antennas, provides an increase in inspection range of more than five times the current one, while the latter may offer increases in inspection range of more than ten times the current one.

InvoDane/Intero, the technology developer, recommended that Phase II of the project develop an engineering prototype for the dual-radio mesh option, and further study the feasibility of the software-defined radio technology in order to better define its potential.

Figure 1: The GL.iNet GL-AR750S wireless system was one of many considered for integration on Explorer

TECHNICAL APPROACH

The project objective was to develop the technology(ies) that will allow the extension of the wireless communication range of the Explorer series of robots. Increased range improves efficiency and productivity of inspections of unpiggable pipelines. The work by InvoDane focused on designing, building, and laboratory testing the deployable antenna systems with their associated mechanisms for attachment to the robot and the pipe. Also, the wireless technology itself was upgraded.

This project was organized in six tasks. At the outset, the focus was on design and included detailed mechanical, electrical, and software design. The drive modules were modified to include the deployable antenna modules. The nose modules were modified to accept the new receivers/transceivers and software. Next, manufacturing and assembly of the range extender antenna modules as well as the deployment apparatus on the drive modules were carried out. The assembled antenna modules were then installed on the Explorer 2026 test robot.

Full system laboratory testing of the new antenna systems was carried out and any needed changes to the design were implemented. Other robot sizes (by pipe diameter) were investigated and challenges that need to be studied with respect to implementing the new system in the other Explorer platforms, from the X6 to the X3036.

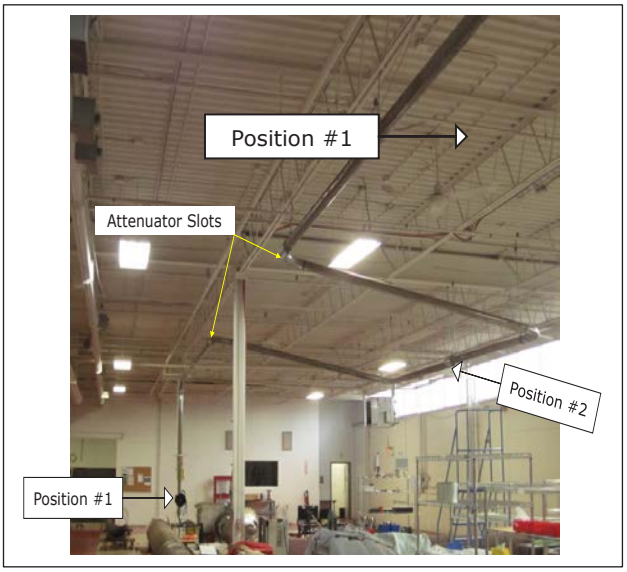

Figure 2: Test Loop for Antenna Deployment

The aforementioned study will indicate whether this basic design concept can be used for the other robot sizes.

Communication protocol enhancements were explored related to the use of software-defined radio as a future, longer term improvement of the com-munication system. Initial results indicate that ap-proach could result in further improvements in range.

Finally, the deliverables for Phase II of the project included a final report which details the final de-sign of the system and testing results and analyses, as well as implications for a future implementation of the software-defined radio communication sys-tem. It also includes a potential plan for the next phase of the project which involves development of the software-defined radio communication op-eration, full

PROGRAM STATUS

The detailed design of the Explorer wireless range extender is complete and a design prototype was successfully manufactured, assembled, and integrated onto and tested on a 26” test robotic platform. The new antenna system was designed, tested, and deployed along with the selection of enhanced communication protocols. A Phase III has been approved to complete field testing of the advanced wireless range extender system.

Highlights

- An innovative antenna system was designed, developed and adapted to the EXP2026 robotic platform.
- Communication protocol enhancements were identified and successfully tested, with a combination of new equipment offering the highest efficiency improvements.

For more information contact:
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Electromagnetic Time Domain Reflectometry (EM-TDR) for Pipeline Integrity

Description: Evaluate and select a non-destructive evaluation (NDE) method to evaluate natural gas transmission pipelines.

Status: Feasibility proven. Field tests pending.

BENEFITS

The benefit of this project is that it allows the development of a new natural gas pipeline Direct assessment (DA) tool for the identification of defects in transmission natural gas pipelines. This method could offer an extended detection length of at least hundreds of meters while providing immunity from background acoustic noise. This tool could provide the industry with a very substantial improvement in DA of natural gas pipelines.

BACKGROUND

Natural gas transmission pipeline integrity is of great interest to the industry and has been the focus of substantial NYSEARCH resources over the last 20 years. NYSEARCH has made major advances in both Direct Assessment (DA) and In-Line Inspection (ILI) of unpiggable pipelines through the development of the Explorer family of robots. DA is still plagued by short ranges, while ILI still requires substantial expenditures in operating the robots, site preparation, and installation of necessary infrastructure. Thus, the need to develop alternative technologies still exists.

ILI offers the highest level of accuracy and the most comprehensive information regarding pipeline integrity. However, given that it is expensive to implement, the use of tools outside the pipeline is desirable as it minimizes cost and does not require tapping into the pipeline, which ultimately may generate safety issues.

Since DA offers limited range and limited accuracy, as compared to ILI, increasing the accuracy and range of DA tools could provide the industry with a substantial increase in defect detection capability at a fraction of the cost of ILI.

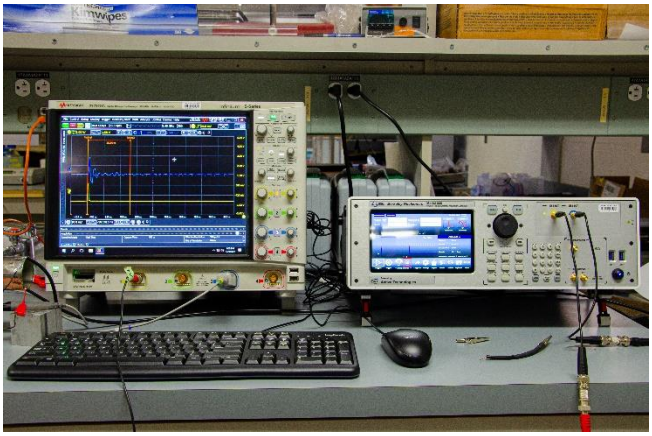

Figure 1: Equipment Set-Up

EM-TDR is a mature technique developed to identify and locate faults in metallic cables. It has evolved to identify and locate discontinuities in the electrical path in printed circuit boards, aviation wiring, and in measuring ground movement in geotechnical applications. An EM signal is emitted in the metallic structure and if the structure has a uniform impedance and is “properly terminated”, there is no reflection of the wave. However, if there is an impedance change at some point from a discontinuity such as corrosion, damage, etc., then part of the wave is reflected back to the source. The magnitude and phase of the reflected wave and the time it takes to return to the point of origin are used to determine the type and extent of the defect and its location along the length of the structure. The wave amplitude, frequency and shape determine the range and accuracy of the technique in the particular application.

Lawrence Berkeley National Laboratory has worked to use this technique in natural gas well environments with some initial success. The method shows much longer inspection ranges than existing techniques, and only requires access to the pipeline at a single point. Variations in materials and pipeline geometry have a significant effect on this technique's performance and tuning.

TECHNICAL APPROACH

The goal of this project was to design, develop, and test a laboratory prototype tool based on EM-TDR technologies, and to conduct a feasibility study to verify the method for use in DA pipeline integrity inspections.

The work for this project focused on building a laboratory prototype system to conduct a feasibility study on the potential of this method to provide DA of pipeline conditions, which included a detailed laboratory and field study to evaluate its ability to detect common defects in natural gas transmission pipelines.

At the outset, the initial feasibility evaluation focused on a literature survey and case studies, including ongoing work for natural gas well applications, to determine system specifications as per established experience. Numerical modeling was used to develop numerical simulations to model natural gas pipeline applications, including initial parameterization studies that included different values of attenuation coefficients, EM signal parameters and pipeline geometry and degradation.

An EM-TDR system prototype was built and its performance was validated through controlled laboratory tests. These initial tasks have provided the critical datasets needed to validate and calibrate the models for initial sensitivity analysis and allowed NYSEARCH to make the first determination that the EM-TDR method is viable for the intended purpose.

Based on the encouraging results of the aforementioned tasks, continuing work will focus on laboratory experiments simulating natural gas pipeline damage scenarios, such as corrosion, metal loss, mechanical damage and cracks, to understand the sensitivity of the EM-TDR signals to well characterized damages. Simultaneously, numerical model improvements will focus on extending the capabilities developed in the baseline models to include simulation for damages under realistic conditions. Upon the successful completion of these last two (2) tasks, NYSEARCH will initiate a pilot scale field demonstration where tests will be carried out in an actual natural gas pipeline for pilot scale system demonstration where comparisons will be made with existing DA commercial systems, such as performance comparison with UT/EMAT systems, to determine commercialization potential.

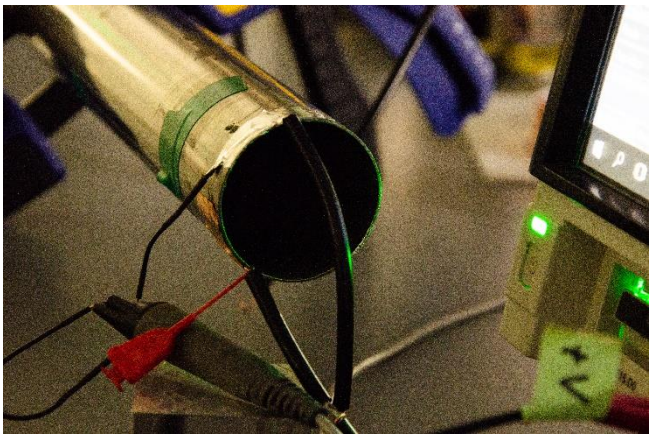

Figure 2: EM-TDR

PROGRAM STATUS

From preliminary studies, there are positive indications that the EM-TDR method and resulting tool could provide a significant improvement in DA of natural gas pipelines in identifying various anomalies.

Highlights

- Numerical modeling and simulations led to prototype development.
- In Phase I, LBNL successfully developed a laboratory prototype for method testing and validation.

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Leak Detection

NGA NORTHEAST GAS ASSOCIATION
NYSEARCH

Technology Brief

Odor Detection Threshold Study

Description: **A study to perform state-of-the-art assessment of detection and recognition thresholds of natural gas odorants.**

Status: **NYSEARCH has developed a database of detection and recognition thresholds for commonly used mercaptans and odorant blends. Testing to quantify the impacts of odor masking agents and Hydrogen blending (up to 20%) is near complete.**

BENEFITS

Odorization of natural gas is considered one of the most significant public health advances of the 20th century and has shown to be the optimal method to warn of a natural gas leak. An updated and quantified understanding of odor thresholds, odor adaptation, odor masking, and impacts of Hydrogen blending using state of the art technology can result in more informed decisions about optimizing the type of odorants used as well as odorant injection levels.

BACKGROUND

The gas industry definition for the "threshold detection level" is the concentration of odorant in air where a change in odor is first perceived. Additionally, the "readily detectable threshold level" is the concentration of odorant where recognition of the odor is achieved. These detection and recognition levels are important because industry safety standards require that natural gas contains a sufficient level of odorant so that it is readily detectable by a person with a "normal sense of smell" at a level of gas in air of 1/5 the Lower Explosive Limit (LEL) or approximately 1% gas in air.

Since 2016, NYSEARCH members have recognized the need for a granular, quantified, and up-to-date understanding of odor detection and recognition. As such, NYSEARCH members have funded a series of studies through Monell Chemical Senses Center, a premiere research center for the study of olfactometry. These studies have centered around the precise quantification of mercaptan/odorant detection and recognition thresholds for humans with a range of olfactory sensitivities. Additionally, impacts (i.e., shifts, reductions, or reinforcements) on those thresholds via phenomena such as odor adaptation, odor masking from agents such as limonene (commonly found in Renewable Natural Gas (RNG)), and due to the blending of alternative fuels such as Hydrogen for decarbonization are being actively pursued to provide critically needed data to decision makers and enhance public safety.

TECHNICAL APPROACH

NYSEARCH members have undertaken a multiphase research project to achieve the goal of this program. The overall goal of this project is to quantify detection and recognition thresholds for natural gas odorants using state of the art technology. Additionally, this project aims to quantify the impacts of various biological processes and RNG constituents which may degrade the efficacy of odorants.

The technology in use for this project by Monell Chemical Senses Center is the Olfactometer, which can deliver the desired test compound or odorant blend in the ppb scale against a background of the desired carrier gas (typically nitrogen in testing). This level of control allows for the design of a battery of tests which provide the ability to chart the thresholds at which participants detect and then recognize odors associated with natural gas. By using a range of odor sensitivity (quantified by Monell as low, medium, or high), the precise thresholds for 95% of the population have been charted and cataloged. The results of these tests have been consistent and typically lower than reported in existing literature.

Figure 1: Test Participants using the Olfactometer

In Phase I, the detection and recognition thresholds for odorant components t-Butyl Mercaptan (TBM), Tetrahydrothiophene (THT), Isopropyl Mercaptan (IPM), n-Propyl Mercaptan (NPM), s-Butyl Mercaptan (SMB), Dimethyl Sulfide (DMS) and four commercially available odorant blends consisting of these compounds were determined with tests of diverse group of individuals in laboratory conditions. This database of laboratory results provides the baseline for the next series of tests which incorporate real world conditions.

In Phase II of this project, building on the library from Phase I, NYSEARCH has begun quantifying shifts in the detection and recognition thresholds through two mechanisms, odor adaptation and odor masking. In the first study of Phase II, the impact of de-sensitization or adaptation to an odorant compound and blend was tested. In this process, the participating individuals were pre-exposed to an NG odorant or blend for a fixed number of breaths. After which they were exposed to a range of odorant concentrations in a blind test to determine and quantify the detection and recognition thresholds shifts.

In the second study of Phase II, the impact of odor-masking agents (such as limonene) will be examined and quantified. In this study, the participant is presented a blend of gas which contains natural gas, the odorant and the masking agent in a blind test. The impact of the masking agents at detectable and supra-detectable thresholds will be quantified and cataloged as the result of this study.

To aid in understanding the impacts of Hydrogen blending, a separate project is underway to quantify the effects that 1%, 5%, and 20% blended Hydrogen will have on the detection and recognition thresholds of odorants. Like the odor masking project, participants will be exposed to various concentrations of odorants against a background of Methane and Methane/Hydrogen blend. The thresholds will be compared to established values from Phase I and provided to funders to aid in adjusting odorization levels when blending Hydrogen in the natural gas supply.

PROGRAM STATUS

NYSEARCH has developed a database of detection and recognition thresholds for commonly used mercaptans and odorant blends. The quantification of: 1) a limited number of odorant compound and blends and, 2) impacts via odor adaptation are complete. Testing for quantifying the impacts of odor masking agents and Hydrogen blending (up to 20%) has yielded results that are being reviewed by project funders. To date, there is no measured impact for blends of Hydrogen up to 20% on the ability of individuals or groups to recognize one of the most predominant odorants, TBM, on the ability to detect the presence of natural gas. Final results to bring confidence to these results are pending.

Highlights

A program to:

- Build a library of up-to-date detection and recognition thresholds for commonly used odorant compounds and blends.
- Quantify impacts of odor adaptation and odor masking from compounds commonly present in Renewal Natural Gas (RNG) on odor detection and recognition thresholds.
- Assess the impacts of blended Hydrogen (up to 20%) on odorant detection and recognition thresholds.

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NGA NORTHEAST GAS ASSOCIATION
NYSEARCH

Technology Brief

First Pass Leak Detection (FPLD)

Description: **A technology advancement and test program to increase the probability of detecting otherwise missed leaks while performing traditional walking surveys**

Status: **Advancements and trials of various instrument technologies, walking patterns and automated survey location records were field tested. The third and final campaign was completed in spring 2023. Final procedures and documents are near complete.**

BENEFITS

The benefit of improved effectiveness in a "first pass leak detection" approach is an overall thoroughness and confidence in detecting leaks. With this more aggressive approach, there is also an increased likelihood of capturing more leaks resulting in increased safety. Operators are keen to reduce missed leaks and increase overall pipeline integrity.

BACKGROUND

There are many instruments and procedures used for performing leak detection within LDCs. Traditional leak detection survey relies on walking with handheld instrumentation by trained and experienced personnel. Mobile and aerial methane detection instruments are also now becoming integrated into leak monitoring practices. Ideally, an optimal leak survey identifies all leaks on a pipeline. The identification of leaks can vary due to weather, ground resistance, migration and other factors. For instance, rain or snow melt can cap or reroute the migration path of the leak, obscuring detection during the leak survey. Also factors such as presence of nearby infrastructure, underground ducts, traffic congestion, number of buildings/obstructions and a range of realistic conditions in LDCs' urban and suburban territories can influence the presence, concentration and dissipation of a pipeline leak.

TECHNICAL APPROACH

The project objective is to evaluate improvements to leak survey effectiveness. Our goal is to optimize use of instrumentation and data acquisition techniques to maximize the detection of pipeline leaks predominantly for walking survey. This is being augmented by other methods to achieve maximum leak detection in one pass.

Commercially available and advanced prototype methane detection instruments have been evaluated. The consideration of a range of technologies will provide an advantage to expanding methane detection capabilities when used in combination during the walking survey. Remote methane leak detection or detection without being within a gas plume, has advantages and disadvantages as compared to open path laser spectroscopy (OPLS), see Figure 2, detection by being within a gas plume (See Figure 1). Combining technologies simultaneously provides improved capability of methane detection during FPLD efforts. (See Figure 2).

Figure 1: RMLD type methane detector with GPS tracking of walking survey and leak location identification superimposed on a street map and gas pipe map

Figure 2: Simultaneous RMLD, FI/GMI and OPLS walking and wearable technologies with leak tracking identification superimposed GPS breadcrumbs on street and gas pipe maps

In addition to selecting optimized methane detection instruments, the project included evaluation of the best walking pattern to take advantage of the differing instruments. Experimentation with patterns of walking surveys has been completed.

This evaluation provides a departure from the typical "H" pattern walking survey, see Figure 3.

PROGRAM STATUS

A Design of Experiment (DOE) has been created and used to capture and evaluate actual results of testing and development efforts. Metrics include tracking, time efficiency and effectiveness in detecting "blind" native and simulated leaks.

Field testing has been conducted at multiple gas company members to apply the FPLD approach in suburban areas and in extreme conditions such as hot desert conditions. The outcome of this development includes a new survey process with a higher probable rate of leak detection and provide the immediacy of leak classification with appropriate crew response and records. It was determined from the two field test campaigns that this approach maximized the potential for finding all leaks.

Figure 3: Leak survey testing

A final field campaign was completed in April 2023. The project results show improved Probability of Detection and provide a framework for optimizing leak detection. The Final Report with analyzed results are being made available for funding members who can use the information with these or similar tools in their leak detection practices. Implementation of the First Pass Leak Detection process could also require investigation of additional costs and how they compare to the added benefits.

Highlights

- Walking survey advancements can take advantage of multiple detection technology simultaneously to approach 100% leak detection
- Field tests have validated framework for members to optimize leak survey proce-

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Pipe Location

RFID Embedded in Coiled PE Pipe

Description: **A project to develop and test an antenna and signal processing system using RFID technology to locate coiled PE pipe that has been installed via trenchless operations.**

Status: **The design and manufacturing of the tag-laying machine and RFID Macrotags are complete. Field testing activities are in progress.**

BENEFITS

The overall objective of the project is to develop and test an antenna and signal processing system using RFID technology to locate PE pipe. The RFID tag will be embedded on coiled PE pipes and is intended for use in all soil conditions. Development was first set to address a 63 mm (2.5") pipe diameter size due to the challenge associated with small diameters (decreased circumferential surface parallel to the ground).

A reliable and accurate method is needed for easier detection of coiled plastic pipe, as tracer wire can become compromised over time. Additionally, one driver for this project was the May 2015 PHMSA Notice of Proposed Rulemaking that outlined requirements for tracking and traceability of plastic pipe. This technology would reduce 3rd party damage, which is the leading cause of pipeline failures. In doing so, it will increase safety in operations as well as enhance the productivity of field crews performing work on the pipeline.

BACKGROUND

Radio Frequency Identification (RFID) technology has been proven and used for other applications such as highway toll readers, retail theft prevention, access control, and asset tracking. A typical system consists of a chip (or tag) and a reader antenna. The tag can operate without a dedicated power source, drawing energy necessary from the reader antenna to transmit and receive data. Information from the tag can be read, but also written via the use of an antenna. Eliot Solutions, a subsidiary of European pipe manufacturer RYB, has a commercially available solution for straight pipe and fittings installed in open trenches that enables operators to accurately identify the location of pipe as well as certain information of interest.

The operating principles behind this technology and its application in straight pipe are well defined and the system is readily available on the commercial market. However, pipe installed via trenchless applications presents a unique challenge to the technology in that the orientation of the pipe cannot be controlled during installation. Thus, NYSEARCH, GRTgaz (formerly Engie), and Eliot Solutions created this project to develop RFID technology for use on coiled pipes installed via trenchless applications.

TECHNICAL APPROACH

NYSEARCH and GRTgaz worked together to develop a set of standards and specifications detailing the requisite performance of the tag when installed on pipe, the manufacturing process, storage, etc. Although the project initially addressed small (2.5") diameter pipes, the technology is scalable up to other sizes. Similarly, all prototypes are being built with high-density pipe, but the design is expected to be transferrable to medium and low-density pipe.

As the specification documents were finalized, iterative design, manufacture, and test processes were undertaken. The RFID tag design enables operators to accurately identify the location of pipes by using three (3) RFID tags to fit 360 degrees around the pipe's outer diameter, therefore ensuring that the tags are always facing the surface and are readable.

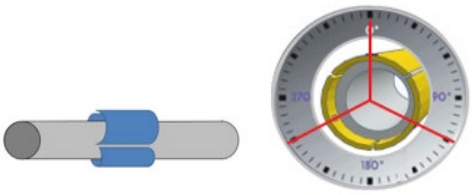

Figure 1: Three RFID Tags for 360° Coverage

In order to fully evaluate the prototypes, GRTgaz used its indoor facility with bays of differing soil types (clay, sand, gravel, topsoil, and limestone) to conduct various underground tests. The network of underground pipes enabled rapid testing at varying depths and in different soil types. This setup simulates real-world environments in which the pipe may be installed.

Figure 2: Test Facility at GRTgaz

The current design allows three (3) RFID tags to be encased in a soft PVC housing flexible enough to be wrapped around the outside of the extruded PE pipe. These RFID tags in the soft PVC housing (referred to as the Macrotag) will be installed simultaneously with the manufacturing of the PE pipe.

Figure 3: Macrotag Installed on PE Pipe

The manufacturing process to extrude the PE pipe and install the Macrotag has also been addressed. To install the Macrotag onto the extruded pipe a tag-laying machine was designed. The tag-laying machine is designed to be integrated into the production line so as not to slow down PE pipe production. The tag-laying machine will secure the Macrotag while simultaneously extruding the PE pipe before being coiled onto the storage drum.

The machine is designed to store enough Macrotag to install one every 65 feet (20 meters) for over 875 yards (800 meters) which is more than the amount of pipe stored on a single drum before the Macrotag needed to be manually replenished.

PROGRAM STATUS

The manufacturing and testing of the tag-laying machine have been the project focus in recent months. Testing in France was completed in early 2023 with eight (8) Macrotag installed every 23 feet (7 meters) onto the PE pipe utilizing the tag-laying machine. This pipe with the Macrotags was then successfully installed via horizontal directional drilling. Eliot was able to successfully read/write to the RFID tags that were buried at 5 feet (1.5 meters) in depth or less which meets the project specifications.

Final testing for this project is planned for summer 2023 and then the next steps will be identified to determine commercial implementation.

Highlights

This technology can:

- Locate coiled PE pipe installed via trenchless applications
- Obtain Tracking and Traceability data from PE pipelines
- Utilize a system that can extrude PE pipe with parallel means for incorporating the RFID Housing

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UTTO vLocate® - Gas Pipeline RTK Mapper & Virtual Locating Device

Description: **Evaluate and test the functionality of the UTTO vLocate tool so that it can be used in the natural gas industry as a high accuracy asset capture device to map buried assets and locate them with precision.**

Status: **Testing feedback of the UTTO vLocate® device has been positive. Final comments are being incorporated into the design.**

BENEFITS

If a low-cost high accuracy GPS tool can be developed with the added ability for data capture and precision relocate-ability, it will provide: 1) a tool for efficiently constructing as-built data; 2) a method for use by non-locate and mark personnel, 3) a simpler approach for asset locating (thereby potentially lowering training and on-boarding time), and, 4) an optional solution in cases where traditional locating methods may not be viable.

BACKGROUND

NYSEARCH members have been specifically interested in asset location technologies to reduce damage to buried assets, especially with the capability to function to enhance traditional locating methodologies. A potential avenue for this capability is the capture and storage of high accuracy Global Positioning System (GPS) asset location data, which ideally would be captured during the as-built process. This data can be leveraged using a high accuracy GPS locator for a variety of end users in the utility's operations groups.

Traditional GPS capabilities precluded this type of application due to the higher than acceptable error in satellite GPS signal locators. A developing capability in use in a variety of industries is leveraging the Real Time Kinematic (RTK) correction service, which is provided by a base station network, which increases the accuracy of the GPS signal.

IPEG has developed a tool that guides a field user to locate back to a specified high accuracy GPS coordinate using an RTK network correction signal with high accuracy.

Previously, IPEG developed a handheld device with PG&E which provides the ability to locate back to known high accuracy GPS coordinates to within 6 centimeters (2.3 inches). PG&E brought this project to the broader NYSEARCH consortium to see if the development of additional capabilities were of interest, such as high accuracy GPS data capture, validation of the technology throughout the United States, and any enhancements that might be identified collaboratively.

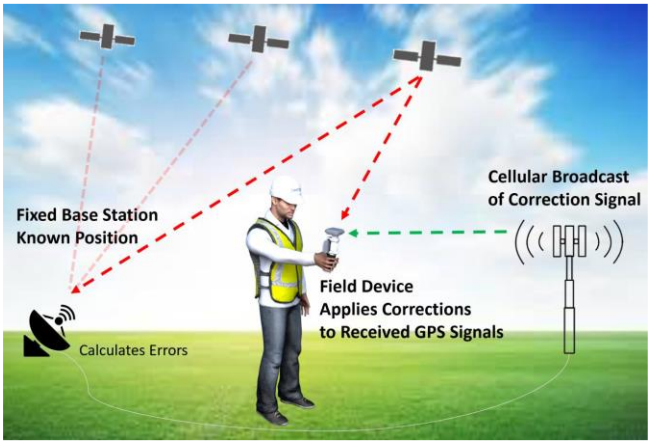

Figure 1: RTK Correction Service

TECHNICAL APPROACH

The objective of this project was to evaluate and test the functionality of the UTTO vLocate®

system, develop new functionality to permit end users to collect high-accuracy GPS data on assets using manually selected RTK networks, and conduct performance testing of the enhanced handheld mapper.

This NYSEARCH project was based on PG&E's prior success with IPEG's tool and the industry's need for tools that expand high accuracy data capture. Based on the success of PG&E's project, NYSEARCH outlined four major sequential work areas to be included in this project: 1) develop functionality to permit end users to manually search and select a public or private RTK network; 2) develop a smartphone application to allow the user to capture and store or recall asset details for precision locating including capture of asset details, including functionality to upload common GIS formats via a cloud dashboard for integration with the utilities GIS systems; 3) enhance the handheld device with a laser alignment tool to allow for accurate positioning and mapping; and 4) improve the user interface design and functionality via field testing with NYSEARCH members and incorporate their feedback.

IPEG separated the development tasks into five categories: 1) workshop and development of specifications, 2) integration of manual RTK correction service selection, 3) development of the mobile application, 4) integration of the laser alignment tool in the existing device, and 5) development of the API to allow import and export via the cloud dashboard view of captured or relocate data.

Functional and field testing utilizing the UTTO vLocate® tool is ongoing. A high accuracy GPS tool that is used for as-built new construction drawings or for capturing data on assets unearthed during maintenance activities would allow a utility to efficiently build a comprehensive database of asset locations over time and will provide a low complexity method for utility personnel to locate assets, thereby lowering the training and on-boarding time as compared to traditional locating methods.

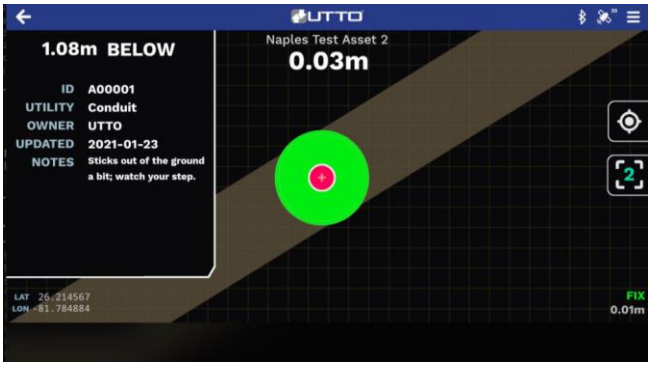

Figure 2: UTTO vLocate® Search and Connect to a Local Available RTK Base Station

PROGRAM STATUS

Overall feedback from testing has been positive. Once IPEG receives all the feedback regarding the UTTO vLocate® field testing, they will incorporate the updates into a more advanced product for release. This project is leading to a product that is optimized for the pipeline industry and commercially available. The final report for the project is issued.

Highlights

- A handheld product has been developed with high accuracy GPS coordinates that is being confirmed as capable of locating assets within 6 centimeters (2.3 inches) accuracy.
- Field testing to date is confirming potential.

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Evaluation of GeoLocation & Pipe Damage Assessment Applications

Description: **Develop and test an above-ground, self-contained measurement system to detect steel anomalies on transmission pipelines.**

Status: **Feasibility proven. Ongoing development of the measurement system and technology.**

BENEFITS

As more stringent regulations are designed and released to address improvements to pipeline safety in an effort to reduce the frequency of pipeline failures, an increased focus has been placed on pipeline inspection, data acquisition, and analysis to increase safety. The benefit of this project is to provide an optimized system to perform ground-based damage assessments of buried steel transmission pipelines with minimal time spent and maximum survey-data analysis to identify potential areas of pipeline deterioration. Identification and remediation of steel transmission pipeline anomalies increase pipeline safety thereby reducing the frequency of pipeline failures.

BACKGROUND

One of the priorities identified by the NYSEARCH consortium has been the location, inspection, and identification of anomalies on buried steel pipe. The natural gas industry inspects buried steel pipelines to detect anomalies such as corrosion, dents, cracks, holidays, etc. Over the years, gas utilities have been developing technology to deal with these issues, and while substantial progress has been made, improvements are still needed to efficiently locate and detect corrosion and damage to pipelines. NYSEARCH identified Skipper NDT as a leading developer of GeoLocation and inspection technology to address this priority.

In 2017, Skipper NDT launched an R&D program to work towards creating an innovative, efficient, and effective way to locate and inspect buried steel pipelines remotely. Skipper NDT has patented a potential solution for transmission pipeline GeoLocation assessment via an Unmanned Ariel Vehicle (UAV a.k.a drone) or a Ground-based Mobile Cart.

The technology is based on remote surface surveys using magnetostatic measurements. The Earth's magnetic field induces a secondary magnetization in the pipeline, which can be detected at the surface. The Ground-based Mobile Cart is equipped with arrays of triaxial flux-gate magnetometers across the pipeline trajectory. These promising results motivated Skipper NDT to pursue further technology development related to detecting anomalies in buried steel transmission pipelines.

Figure 1: Ground-based Moblie Cart

TECHNICAL APPROACH

In 2019, in conjunction with the Ecole et Observatoire des Sciences de la Terre (EOST), Skipper NDT began working on a new complementary survey method using an active magnetostatic source. The resulting development efforts, covering the initial concept through early research, proved that the

The objective of this project is to develop and test an above-ground, self-contained measurement system to detect steel anomalies on transmission pipelines. The starting point of this project was to utilize the proven hardware previously developed by Skipper NDT as features for this project. Additionally, the evolved design was integrated onto the previously built test bench. The measurement system resides on a vertically moving platform in the tower to scan at various heights along a sample pipe.

Figure 2: Test Bench with Movable Tall Tower

The new design was initially conceived as modular to accommodate design changes and upgrades. The rectangular-frame coil is mostly a mechanical design that is embedded into the tower rack and will later be self-contained, easy to manufacture, and installed into a field-worthy system. The source-current power supply is mostly an electronics design that will be upgraded in several steps to a fully automated system. The positioning and data-acquisition system is already proven and will be used for further developments.

The current-supply for the active source coil was developed separately from the actual coil. The sensor array and positioning system did not require any modifications from the previously developed system. The current-supply electronics were designed as a very simple circuit with three submodules; a power supply, current measurement, and mode-control cascade-switching array.

Concurrently during development, NYSEARCH hosted a field test utilizing Skipper NDT's UAV platform near Norwich, NY in NYSEG service territory. This demonstration survey showed the efficiency of the technology to remotely determine the pipeline position in field conditions. This system conducted magnetic measurements over buried pipelines and provided an accurate 3D position of the pipelines.

PROGRAM STATUS

The active source system was developed in two independent modules: an active source with its frame and connector cables and a source-signal generator. The data acquisition protocol and instruments from the passive-survey system with the magnetometers and the positioning system were successfully used, the test bench was realigned, and the positioning system has been optimally integrated with the newly realigned test bench.

A series of measurements were taken on an actual 6" pipe exhibiting corrosion utilizing the newly designed system and the results were encouraging. Overall, the development of the active-source survey system is progressing according to schedule. The current design serves to completely replace the functionality of the measurement system from EOST and improve its shortcomings.

Highlights

- Successfully field tested the GeoLocation technology via UAV.
- Early-stage test results show the technology can detect corrosion.

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Real Time Sensing & Inspection for Distribution

sUAS (drone) Inspection of Submerged Pipe

Description: **Develop sUAS technology to perform enhanced leak detection surveys and mechanical integrity inspections for submerged gas pipelines.**

Status: **Feasibility proven. Ongoing development/testing of the measurement system and technology.**

BENEFITS

NYSEARCH has made investigation of technology to improve leak detection surveys and integrity inspections a research priority. NYSEARCH has invested considerable resources developing sUAS technology applications for enhancing traditional inspections and surveys. Expanding development of sUAS technology into assessing submerged gas pipelines would further the practical capability.

BACKGROUND

Continuing testing activity in the sUAS program expands applications and confirms that the gas industry can take advantage of the enhanced capabilities of these small remotely controlled platforms and sensors for routine and emergency surveys and inspections.

Phase I of this project focused on submerged pipe applications and tested multiple sUAS, barge and submersible drone configurations. A variety of sensors were evaluated, tested, and either rejected for not satisfying measurement criteria or accepted for further incorporation into mounted positions on the specific drone platform. Initial operational controlled laboratory and field testing were performed to develop operability movement and patterning.

Initial testing of capabilities for identifying and measuring leaks from submerged pipelines included testing sensors considered capable of differentiation between methane-only biogenic sources with methane/ethane thermogenic gases (pipeline gas mixture) to confirm gas origination. It was suspected and confirmed that both sources of gases coexist near one another and must be distinguishable during a leak survey.

Initial testing for pipeline integrity assessments explored tactics for using drones to perform cathodic pipe inspections on submerged pipe by collecting close-interval-survey (CIS) measurements underwater. An array of half-cells was affixed to an underwater drone platform to collect CIS readings with a data logger.

The results of the Phase I project, with its related and active predecessor project M2019-003 *Expanding sUAS Technology Assessment for Data Analytics and Advanced Sensing,* have demonstrated that multiple remotely operated platforms of airborne sUAS, water surface barges, and underwater submarines incorporating various sensors, effectively perform leak survey and pipeline integrity inspection on submerged pipelines.

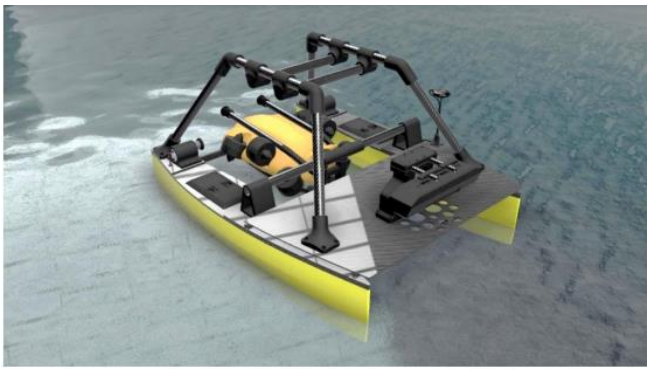

Figure 1. Surface barge transporting and launching submersible diving tool, ROV.

TECHNICAL APPROACH

The objective of this project is to develop technology to perform enhanced leak detection surveys and mechanical integrity inspections for submerged gas pipelines. The previous phase of the project provided full development and

conformation of the platforms, sensors, and operating procedures.

The goal of the current phase is to advance and optimize the configuration of these remotely operated platforms, sensors, and field survey and inspection processes, so that they can be adapted within a pipeline operator's integrity management protocol or adopted by their commercial service provider performing leak surveys and pipeline integrity inspections.

EagleHawk, the selected contractor, is addressing three (3) additional tasks to achieve the goal of advancing the configuration of these remotely operated platforms, sensors, field surveys, and inspection processes. At the outset, the first task was to select the optimized drone platform configuration based on laboratory and field testing conducted during the previous phase. This task included optimization of sUAS, barge, and submersible remote operated platform (ROV) with specific instrumentation.

Figure 2. Submersible pipeline inspection.

After selecting the appropriate technology, three (3) funder field test locations were identified and performed for final modification to the hardware, software and operating instruments. Optimizing the flight pattern during the survey or inspection allows the broadest application of data capture. It also enhances post processing of survey and inspection results, such as color-coded leak detection measurements superimposed on maps and related heat maps of gas plumes.

Each field test was reviewed and evaluated for possible lessons learned for improvements to the platform configuration and operating instruments. Summary documentation detailing the required hardware, software and flight controls for the funder, or their commercial drone service provider, to use to implement the technology within their company protocols is being provided.

Final deliverables include providing a final sensor and platform configuration for the sUAS, barge, and ROV to achieve reliable inspections and survey results leading to readiness for funders and operational procedures.

PROGRAM STATUS

As Phase II is nearing completion, EagleHawk has narrowed down the most effective sensors, sUAS/barge/ROV applications and test procedures. In the last tasks, additional development and testing is providing final field test confirmation of the processes that are ready for commercialization.

Highlights

- Documentation including the required hardware, software, and flight controls for program implemenetation have been prepared and will be available for funders.
- Multiple remotely operated platforms of airborn sUAS, water surface barges, and underwater submarines (ROV), equipped with sensors, effectively perform leak survey and pipeline integrity inspections on submerged pipelines.
- Corrosion assessment on submerged pipe and close interval survey (CIS) technique performed from the barge and ROV platform are under test.

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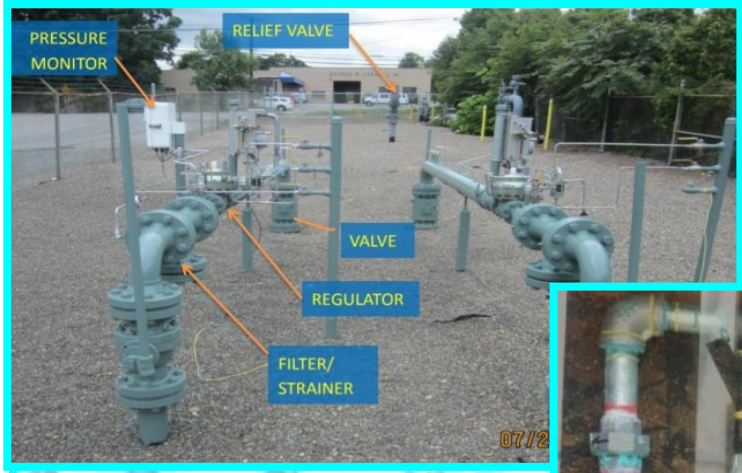

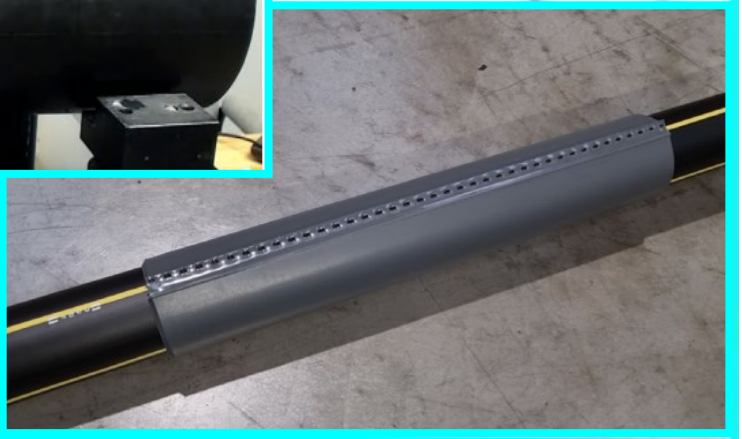

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