Northeast GAS ASSOCIATION

NYSEARCH 2021 Report

Research, Development and Demonstration Program

www.NYSEARCH.org

2021

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

The Value Proposition of Collaborative R & D

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).

The knowledge that member companies provide spans a wide range of areas. Notably there is great commonality among gas LDCs regarding similar operating problems and techniques for addressing those problems. 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.

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 that have come from initial ideas brought by one member that others could endorse. 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. 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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Technology Brief

An Energy Harvesting System for the Extension of the Range of the Explorer Robotic Platforms

Description: **A system that utilizes the flow in a natural gas pipeline to generate tow force and electric power to drive the Explorer robots and extend range of operation.**

Status: **Technology development is complete. The system is expected to be available for commercial deployment in 2022.**

BENEFITS

The commercial Explorer robots carry on-board batteries that provide all the power needed for operation. As a result, the range of the robots is limited by the on-board power that is available. To improve Explorer's operational range by utilizing gas flow that is available in the pipeline, NYSEARCH sponsored a project to: 1) develop a module that would use principles of Energy Harvesting in order to minimize or possibly eliminate power drawn from the robot's batteries when traveling with the flow, 2) generate a tow force for propelling the robot, and, 3) charge the robot's batteries using the available gas flow instead of above ground attached equipment that is currently used. Current equipment requires expensive excavation, hot tapping of the pipeline and long periods of idle time.

Extending the range of the robots would result in significant operational efficiencies and cost reduction, especially for long inspections.

BACKGROUND

The Explorer family of robotic inspection tools is designed to inspect unpiggable natural gas pipelines for integrity and safe operation. They are deployed under live conditions through off-the-shelf pipeline hot-tap fittings and do not require the pipeline flow to be reduced or shut down during operation. A series of six different size robots allow us to inspect pipelines in the range of 6" to 36". These tools carry MFL (Magnetic Flux Leakage) sensors to measure metal loss in the pipe due to corrosion, and optical mechanical damage sensors to identify and measure dents and pipe ovality. What makes the Explorer robots unique is that they are untethered, remotely controlled, and self-powered via on-board batteries. Additional sensing and operational capabilities have been developed that complement the MFL and mechanical damage sensors to offer a wide range of unpiggable pipeline inspection services.

TECHNICAL APPROACH

The objective of this project was to take the concept developed in the earlier work and build a full-scale pre-commercial prototype system for integration aboard Explorer 20/26 (the robot designed for inspecting pipe sizes of 20" to 26" in diameter). The goals were to develop the system such that the unit can be operated effectively, safely, and efficiently within the pipeline environment, including ease of deployment, ease of operation, and ease of maintenance.

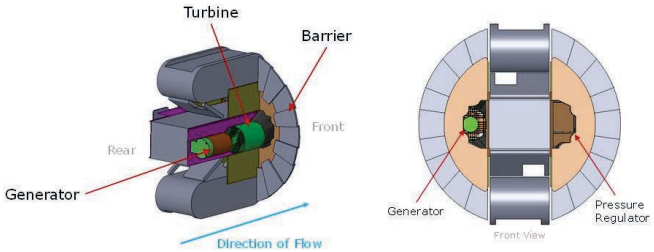

Figure 1: Energy harvesting module concept

The resulting system uses a deployable barrier, which utilizes gas flow to generate a tow force on

the robot; a pressure regulator valve for fine adjustment of differential pressure across the barrier; and a turbine/generator combination to generate electrical power that can be either directly consumed to power the robot or be stored in the on-board batteries for future use.

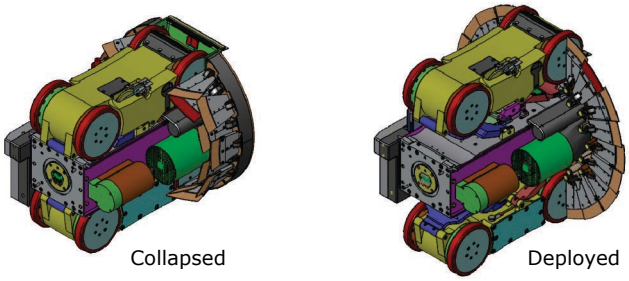

Figure 2: Energy harvesting module design

A laboratory test setup capable of testing a stand-alone energy harvesting module as well as one integrated on an Explorer 20/26 robot was used to evaluate key parameters and basic functionality. Data that was collected was used to compare predicted performance to actual with particular interest in validating the turbine simulation models developed by Concepts NREC, who were contracted for turbine design.

PROGRAM STATUS

This project has resulted in the successful development of a full-scale pre-commercial prototype that can be operated effectively, safely, and efficiently within the pipeline environment. The most notable achievement of this work was that the energy harvesting module, when tested in a 24 inch live gas transmission pipeline, successfully met its major objectives. While traveling with the flow, all power was supplied by the energy harvesting module. Testing of the batteries via the turbine while in the pipeline showed battery charge rates comparable to the above ground in-line charging system currently in use. The test also highlighted some areas that needed improvement, namely in barrier design and in electrical, mechanical, firmware, and user interface systems.

Such improvements were implemented following the field trial resulting in a more robust pre-commercial system. This system is now ready to be deployed later in 2021 as part of a limited number of select commercial jobs of Explorer 20/26 in order to collect more data and test its functionality for extended periods in real live pipeline environments for further validation. It is anticipated that full commercial deployment will occur in 2022.

Figure 3: Live deployment in 24" gas pipeline

For more information contact:
admin@NYSEARCH.org

Highlights

- Energy harvesting system utilizing gas flow to propel the Explorer robots, provide tow force, and store excess power produced in onboard batteries.
- Under optimal flow conditions, ability to power the robot without use of batteries.
- Under non-optimal flow conditions, ability to use combination of tow force, batteries, and live power generation.
- Substantial reductions in deployment cost for long inspections.
- Improved safety and operational efficiencies.

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Technology Brief

Weld Crack Sensor for Inspection of Unppiggable Pipelines via Explorer Operations

Description: **A project to develop technologies for detecting cracks along the seam weld in unpiggable natural gas pipelines.**

Status: **Ongoing optimization of seam weld detection measurement and module features.**

BENEFITS

The use of the weld crack sensor will allow the deployment of the Explorer 20/26 robot to detect cracks during an inspection of natural gas pipelines. The detection of cracks has been a primary interest to the gas industry, especially flaws along seam welds. Seam welds are the most probable location for cracks in the natural gas pipelines.

A successful completion of this project will allow the deployment of a crack sensor on the Explorer robot for the inspection of natural gas pipelines. In a single deployment, the Explorer will be able to provide data for corrosion defects via the axial Magnetic Flux Leakage (MFL) sensor, mechanical/ovality damage via the Laser Deformation Sensor (LDS), and crack defects via this weld crack sensor. This will provide a substantial improvement in operational efficiencies and cost reduction in inspection operations.

BACKGROUND

The sensing capability that was originally developed for the Explorer robot was tailored to detecting corrosion damage. Then starting in 2013, the LDS was developed to detect dents and ovality for the Explorer robot. This was integrated onto the Explorer 20/26 platform to identify any mechanical damage on the pipe or ovality of the pipeline during axial MFL inspections. However, there was still a need to develop additional technologies to detect other sources of damage such as seam weld cracks.

The existing MFL sensors magnetize the pipe wall in the axial direction thus providing excellent capabilities for corrosion defect detection. One of the areas with reduced sensitivity with this arrangement is axially aligned anomalies, such as cracks. When rotating the magnetization 90 degrees, detection of axially aligned cracks can be achieved. This is also known as Transverse Magnetic Flux Leakage (TMFL). A second approach Electromagnetic Acoustic Transducer (EMAT) was also integrated onto the Explorer 20/26 robot. However, due to the size of the sensors the technology could only be used on larger sized robots, a third method, the Anisotropic MagnetoResistive (AMR) Eddy Current (EC) technology, was developed and integrated onto the smaller size robots.

TECHNICAL APPROACH

This project is intended to incorporate the successful technology of the TMFL, EMAT and EC onto a smaller and lighter module that can be mounted directly onto the Explorer 20/26 robot. It is being used to inspect the seam welds; the place where most of the cracks appear in pipelines. Given its relatively small size, it is being mounted on the joints of the Explorer platform and will not require an entire module. Thus, it is capable of deployment onboard the Explorer in conjunction with the standard axial MFL sensor module for corrosion detection and the LDS for mechanical/ovality detection.

Figure 1: Explorer with Weld Crack Sensors

The overall concept for this weld crack detection system involves the use of two custom steer modules. Each module is equipped with a magnet bar featuring a large two-dimensional sensing array. These two modules will work in concert to scan the long seam weld in its entirety. This design requires additional investigation into MFL signal signatures of girth and seam welds in a variety of pipe constructions and testing of routines in a lab environment.

To conduct a continuous scan, the robot is moving while it is scanning the pipe without stop, start, or reverse maneuvers. The use of two sensors allows for a full data set for each seam weld in a pipeline. The two modules are identical in design and include a TMFL sensor tailored to this application.

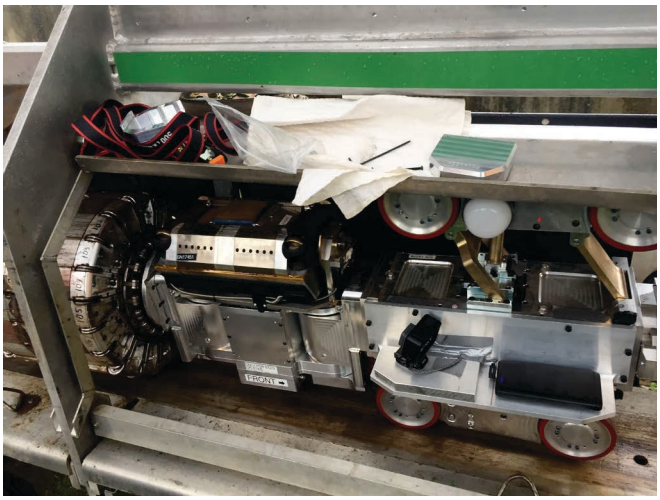

Figure 2: Weld Crack Sensor at NYSEARCH Test Bed

Additionally, the operator Graphical User Interface (GUI) for the weld crack sensor was integrated with the overall robot GUI to simplify the operation of the robot and weld sensor functions all on one screen. The weld crack sensor GUI added live tracking data and signal graphs to show the operator the current weld crack detection status on the GUI screens.

In-field functionality of the weld crack sensor module was tested at the NYSEARCH Binghamton Test Bed. The laboratory and field tests successfully demonstrated that this weld crack sensor can collect data from long seam welds without requiring a separate scan. However, improvements are being addressed to commercialize the weld crack sensor.

PROGRAM STATUS

The sensors are being optimized to reduce the size and weight of the overall modules to ensure a safe and seamless launch and recovery in and out of the pipelines. Additionally, the sensor system is being optimized to improve and refine the crack detection.

The weld crack sensor GUI has been integrated into the commercialized robot GUI to allow the control of all robot functions under the same user interface.

This new weld crack sensor system is being field tested on the Explorer 20/26 robot at the NYSEARCH Binghamton Test Bed. The test is intended to validate the tracking and detection anomalies in long seam welds and the data analysis procedures.

Highlights

- Single deployment for mechanical damage, corrosion defects, and seam weld cracks
- Lower inspection cost due to single deployment

For more information contact:
admin@NYSEARCH.org

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Technology Brief

Enhancements of Explorer Operations via Automation

Description: **A project developing technologies for the automation of most routines that control the operation of the Explorer series of Inline Inspection platforms for unpiggable Natural Gas Pipeline.**

Status: **Completing advancement of software routines that will automate major Explorer functions, allow feature detection, and provide mapping capabilities of pipeline features.**

BENEFITS

The operational complexity of running the Explorer systems, a series of robotic platforms designed to inspect unpiggable natural gas pipelines, can be seen in the level of expertise that is required from the operators during all phases of an inspection. To achieve proficiency, a large amount of effort is placed in training personnel to set up and drive the robot through the pipe in a safe and efficient manner, and to collect quality data. For instance, normally the operator is required to check each module and the entire system during pre-inspection functionality checks. During the inspection, the operator manually drives the robot into the pipe and maneuvers each module according to the requirements of individual features. Upon exit from the pipe, the operator is required to diagnose the state of the robot and determine maintenance needs. The complexity of manually executing these routines during operation sometimes results in longer than necessary times to operate the robot, non-optimal operational reliability, robustness, and data quality.

Figure 1: Commercial Explorer 20/26 Robot

The overall objective of this project is to reduce the level of operational complexity associated with deployment of Explorer, an innovative and complex system, while increasing its overall capability. One way to achieve this is to impart some designs in the way that Explorer is controlled in and out of the pipe. By simplifying this aspect of the technology via automation, we can potentially increase robot range, reduce number of personnel onsite, improve pipeline data quality, and add robot robustness (reduced operational risk). Such improvements can then add higher resolution and detail for each inspection, reduce operational risk, lower deployment costs and further increase safety.

BACKGROUND

In 2010, NYSEARCH initiated the process of commercializing a full range of Explorer robotic platforms to conduct ILI of unpiggable pipelines via our commercial partners, InvoDane Engineering and Pipetel Technologies. Currently, robotic devices can inspect unpiggable natural gas pipelines in the range of 6 to 36 inches under live conditions measuring corrosion and mechanical damage/ovality using an axial Magnetic Flux Leakage (MFL) sensor and an optical mechanical damage sensor respectively. Video imagery and integrity data acquired by the Explorer robots are analyzed by Pipetel using proprietary software. Further, crack detection capabilities are being added.

Currently, the operation of these robots is done manually by operators that are trained extensively to safely drive them through difficult and challenging maneuvers. Automating steps to control the robot, during all phases of an inspection (pre-inspection, inspection, post-inspection, and analysis), represents a key opportunity to reduce costs of inspection and increase the robustness of the inspection process while improving data quality.

A feasibility study was initiated in 2017 that developed automation routines using the existing sensory and control technology on the Explorer robots. The study identified those sensory and control technologies that needed to be added to further enhance the capabilities of the robots to achieve autonomous operation.

TECHNICAL APPROACH

To achieve the goal of autonomous operations, two key capabilities were identified for further development: automation of control module and further development of pipeline mapping.

The Explorer's drive module was redesigned to incorporate the automation computer and Inertial Measurement Unit (IMU). To further enhance the robot's feature recognition, a 3-dimensional camera was developed and incorporated onto the front of the Explorer robot. The 3D camera is designed to recognize many pipeline features including bends, tees, offshoots, and obstacles. To increase the robustness of the system, the 3D camera was tested to withstand the pressurized pipelines.

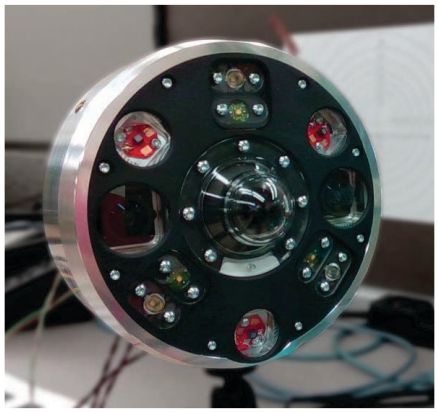

Figure 2: Explorer 3D camera prototype

Furthermore, pipeline mapping has been updated to assure the accuracy of the robot while autonomously navigating the pipelines. This update includes an IMU on the Explorer robot and the techniques to post-process the IMU data for accurate pipeline mapping. The IMU works by measuring the acceleration and rate of the robot, comparing the data to its internal odometer to determine the location within the pipeline. Additionally, to maintain the robustness of the Explorer robot, the IMU is designed and tested to withstand the pressurized pipelines.

PROGRAM STATUS

The sophistication of the robot navigation software and pipeline mapping is being refined.

The first field test is being conducted during a commercial inspection to test the full system functionality and ensure that the system is robust for field use in live pipelines. Additionally, the field test is confirming the existing commercial functionalities, the Laser Deformation Sensor (LDS), and navigation video to ensure they are operating at the same performance levels or better than the current commercial system.

Highlights

Automation of robot operating functions and development of feature recognition routines will allow:

- Longer robot operational range
- Lower number of personnel on site
- Lower deployment costs
- Higher quality data
- Higher robot robustness
- Lower operator training costs.

For more information contact:
admin@NYSEARCH.org

Liquid Capable Explorer for Inspection of Unpiggable Pipelines with Liquid

Description: **Design, testing, and implementation of technology to enhance the Explorer 20/26 series of inspection platforms when liquid is present in live unpiggable pipelines. This technology will ultimately enhance Explorer's ability to conduct In-Line Inspections (ILI) when encountering liquids.**

Status: **Development and testing tasks are in progress.**

BENEFITS

The overall objective is to develop and test the Explorer 20/26 robot capability to drive and scan through accumulated liquid in natural gas pipelines. Thus, we are working to further enhance the capability of driving and scanning through large and small amounts of liquids.

Based on a detailed technology assessment in 2019, it was determined that the Explorer is better suited to drive through the liquid versus cleaning the liquid in pipelines as it is a more cost-effective solution in live natural gas pipelines. This new capability would enable the Explorer 20/26 robot to conduct inspections where previously, in those cases, the inspection job was halted or segmented because there was liquid present in the pipeline.

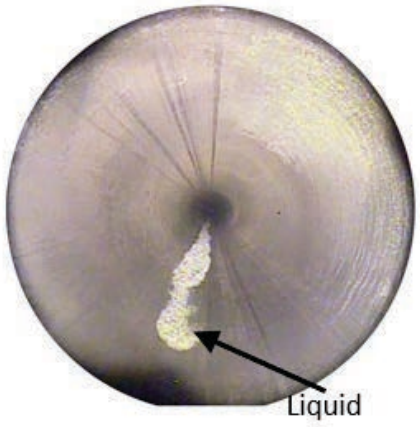

Figure 1: Rare case of accumulated liquid in pipeline

At the conclusion of this project, the work will result in the development, testing and commercialization of the first technology able to traverse and scan through liquids in an unpiggable natural gas pipeline. This technology will enhance our ability to inspect unpiggable pipelines in cases where liquid is present.

BACKGROUND

Previously, the Explorer robots were designed to accommodate a small amount of liquid in the pipeline during an inspection, but there was still a need to address inspections with larger amounts of liquid that could potentially damage the sensors and negatively impact the sensors' readings. When there is a certain level of liquid in the pipeline, it can result in the Explorer robot not being able to complete the scan; thus causing the inspection to be less efficient and timely. Subsequently, other liquid extraction methods were considered necessary. If implemented, the robot would then be introduced back into the live pipeline to continue the scan once the liquid was extracted.

NYSEARCH first funded and developed a cleaning tool for dry debris for the Explorer 20/26 robot. The cleaning tool for dry debris was extensively tested in the lab and in the field. This cleaning tool demonstrated a capability for removing dry debris and only small amounts of

liquid. Therefore, the additional capability to remove large amounts of liquid was addressed in this separate initiative.

It is noted that the number of commercial inspections where the Explorer robot has encountered liquid has been minimal. Thus, in a study to address removal of liquid showed that the additional cost and logistics that were required were not practical. Thus, the NYSEARCH funders decided to ruggedize and change the Explorer design to drive and scan through liquid.

TECHNICAL APPROACH

In historical commercial jobs, the Explorer used the Magnetic Flux Leakage (MFL) sensor which is lifted to minimize the impact of the pooled liquid as the robot passes. Thus, when lifted, the data is missed for that section. This project focuses on developing and testing a liquid-resistant Explorer 20/26 robot that can traverse and scan in such conditions.

Based on an extensive database of Explorer commercial jobs, the average amount of liquid was calculated to determine which components of the robot would be affected. With that information, the approach was to waterproof the sensors closest to the pipe wall to assure that the Explorer can produce effective scans through any amount of liquid. The major components were tested for vulnerabilities using liquid penetration tests and compressed air tests to aid in the discovery of liquid vulnerabilities. Specifically, liquid reactive paper was used in submersion tests to discover leak paths. Once the vulnerabilities were fully established on the components, additional hardened prototypes were designed and retested.

In addition, some of the liquid ingress points as well as liquid sensitive components were identified, and various sealing methods were studied and calculated to aid with the selection of the right sealing method for the right component.

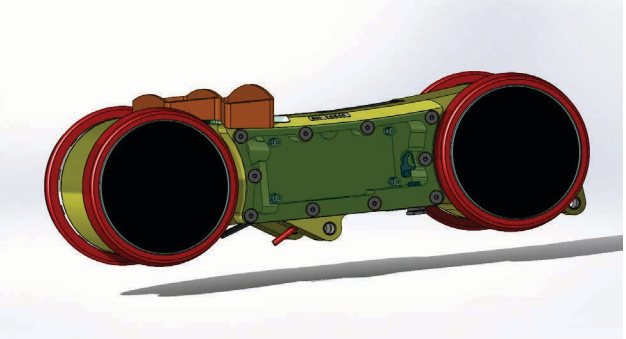

Figure 2: Liquid Capable Explorer Drive Track

Some of the improvements made on the drive tracks included a “snorkel fitting” to aid in the pressure-equalization of the drive tract to the pipeline pressure.

PROGRAM STATUS

The drive track and magnet bar prototypes proved that a liquid capable robot is possible. Thus, the alpha prototypes are being further developed into functional prototypes to be incorporated onto the Explorer 20/26 robot.

The intent after the design and testing is to retrofit a set of subsystems for the existing models. Additionally, the liquid capable design will be incorporated on future generations of robots to ensure all robots can effectively traverse and scan through accumulated liquid.

Highlights

Technology is being enhanced so that:

- The Explorer robot that can traverse and scan through liquid in pipelines.
- The improved Explorer robot can enhance the efficiency and reduce inspection costs in cases where liquid is present.

For more information contact:
admin@NYSEARCH.org

Improved Installation Maintenance & Repair

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Technology Brief

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

Description: **A technology automation project to compare critical flaw characteristics in PE pipe joints based on established acceptance criteria**

Status: **NDE automation algorithms are being developed with machine learning techniques to determine the impact on integrity of PE pipe butt fusion joints**

BENEFITS

Automation of Nondestructive Examination (NDE) processes comparing joint interrogation results with known acceptance criteria would provide insight to a non-expert inspector deciding to pass or fail a field-fabricated joint. An automated algorithm provides a simple pass/fail indication from NDE results that visually indicates 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 rolled back beads at the butt fusion interface. ASTM F2620 provides guidance for visual inspection based on the observation of the resulting joint configuration. The final check of acceptance to 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 result to be useful.

Previous NYSEARCH projects were successful in obtaining critical flaw characteristics and acceptance criteria for PE pipe butt fusion joints. Also, 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). 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 them 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 based development of the automation on the NYSEARCH critical flaw characteristics and acceptance criteria information which is essential in setting bounds for the pass/fail interpretation.

The Eclipse Scientific automated 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 new and improving NDE techniques are developed, they provide more in-depth insights to the butt fusion joint flaw detection and the algorithm can be modified to incorporate the advanced NDE technique; thus, continually improving the overall interrogation results.

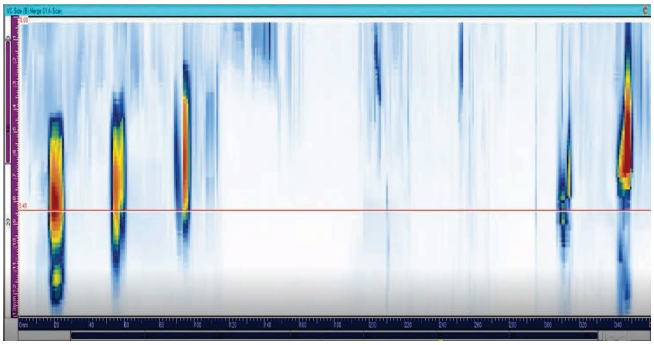


Figure 2: Typical initial results from PAUT NDE detecting anomalies within a PE pipe joint

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.

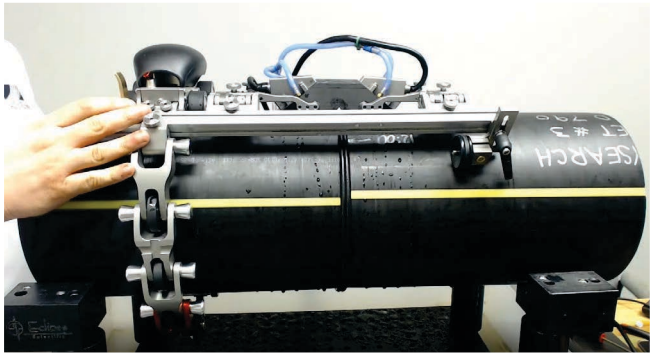


Figure 3: Typical application configuration of PAUT NDE inspection of a PE pipe joint

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

Planning for trials in gas company laboratories and actual field trials are being scheduled.

For more information contact:
admin@NYSEARCH.org

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 to be provided on tool display with a simple red/green indication of the probability of joint failure

Northeast GAS ASSOCIATION NYSEARCH

Technology Brief

Multi-Tech NDE Test Program for PE Pipe Joints

Description: **Create a standardized approach to thoroughly test and validate current and emerging non-destructive (NDE) testing technologies**

Status: **NDE Technology Providers have been identified with interest in participating in the testing for this standardized approach. The standardized test process and "blind" PE pipe samples are being designed.**

BENEFITS

An NDE technology that would inspect PE pipe joints and use a standardized method would be a benefit to gas industry by validating stated NDE capabilities for the LDC application. LDCs reliance on extensive training of PE pipe butt-fusion fabrication procedures and processes provide confidence that visual inspection of a final melt fusion beads is effective. Additionally, NDE would provide further insight to the material fusion within the volume of the joint, see Figure 1.

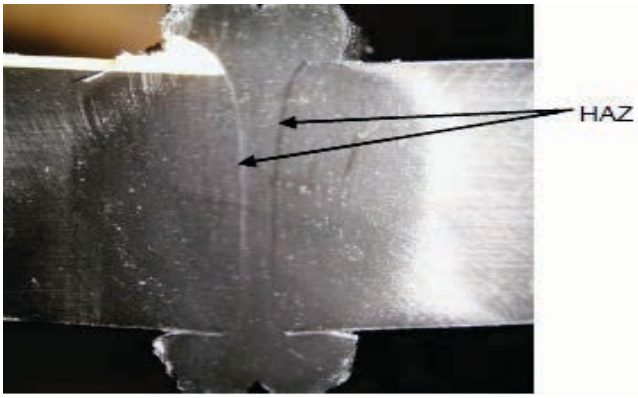


Figure 1: Cross-section of PE butt-fusion joint

BACKGROUND

The LDC's interest in an effective NDE technology to inspect plastic gas pipe joints is a high priority. Industry regulatory groups are also encouraging the LDCs to bring effective NDE technology to enhance common operational practices.

Currently, there is no standardized evaluation program to verify NDE technology performance capabilities. NYSEARCH members requested that a standardized NDE evaluation and validation program be prepared. The program is designed to include effective testing techniques for assessment of existing NDE technologies and for testing advanced emerging NDE technology still in development.

This standardized test program will utilize a unique PE pipe defect sample library to evaluate and validate any NDE technology. With this program, the practicality of field implementation of the NDE technology will also be assessed.

TECHNICAL APPROACH

The objective is to define and prepare a standardized program that allows NYSEARCH to validate for its members any NDE technology that can assist in assessing plastic pipe joints.

Testing and validation of a NDE technology will progress through these steps, see Figure 2.

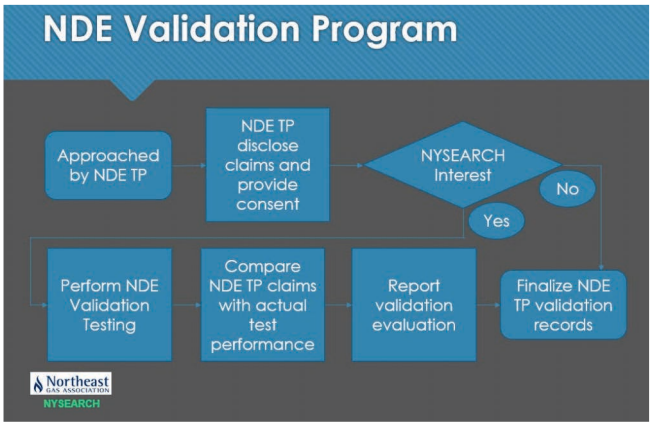


Figure 2: Illustration of the progressive flow chart - NDE Validation Program

1) The NDE Technology Provider (TP) discloses their instrument's capability and expected performance. This information is provided in advance of testing for con-

sideration by the LDCs to determine if there is a commitment to the evaluation of the instrument within the standardized testing program. It also provides details of the instrument to be validated during the testing, describing both the science within the instrument and the application requirements for practicality applying the instrument in the field.

2) The LDCs review the NDE technology provider's instrument disclosure and decide on proceeding with the standardized test program. The NDE technology provider is invited to participate in demonstrating their NDE technology and its capability with NYSEARCH's "blind" defect sample library, see Figure 3.

3) NYSEARCH evaluates the effectiveness of the NDE technology providers performance by comparing the NDE technology interrogation results with the actual flawed sample joint conditions. A statistical approach is used to determine qualitatively and quantitatively accuracy of the NDE technology in detecting flaws.

4) The initially stated claims from the NDE technique are compared to the actual test results. Differences are identified and described in the resulting NYSEARCH test report.

The final test report will include the results of the NDE technology testing process, accuracy of the technology, confirmation of claims and notes regarding field practicality.

Figure 3: NYSEARCH sample library of all known defects found in the gas industry impacting PE pipe joint integrity

PROGRAM STATUS

Several NDE technology providers have confirmed interest in testing and validation of their NDE technology through the NYSEARCH standardized process.

NYSEARCH is nearing completion of fabrication of the defect library of PE pipe butt fusion joints.

The scheduling of NDE technology providers for participation in this testing and validation program is being planned.

For more information contact:
admin@NYSEARCH.org

Highlights

- Standardized NDE technology evaluation and validation process for LDCs
- A statistically based test approach that repeatedly uses standard defect samples for all NDE technology validation evaluations
- Consideration of other possible NDE technologies continue, inclusion in this program where applicable

Northeast GAS ASSOCIATION
NYSEARCH

Technology Brief

PE Pipe Repair Methods – Butt Fusion Repair Sleeves (BFRS) and Variable Length Repair Sleeves (VLRS)

Description: **A permanent repair technique for damaged, non-leaking PE pipe.**
Status: **PE pipe sizes of 1 1/4 inch through 12 inch are commercially available**

BENEFITS

Permanent and safe PE pipe repair methods can avoid cut-outs and potential customer interruptions. NYSEARCH's development of butt fusion repair sleeves (BFRS) and variable length repair sleeves (VLRS) for Medium Density and High Density PE piping, operating within gas distribution pressures of 125 psig, provide repair options for damaged, non-leaking PE pipelines. Repairs are performed in-service without stopping or by-pass of normal operating gas pipelines.

BACKGROUND

NYSEARCH has completed an extensive development and test program for a range of gas industry PE pipe diameters repairable with BFRS and VLRS fittings. That program and the commercial release of associated tooling led to funding member availability of BFRS and VLRS repair fittings for 1¼", 2", 4", 6", 8" and 12" diameters.

There are clear economic and safety advantages inherent in the ability to repair in-service PE pipe without the need to squeeze-off, build a by-pass or excavate to access the pipe. The designed repair approach of the BFRS and VLRS provides a full circumference enclosure around damage from gouges or scratches.

TECHNICAL APPROACH

The project objective was to develop butt fusion repair sleeves (BFRS) and variable length repair sleeves (VLRS) for distribution gas PE piping (up to 125 psig). The repair technique using these fittings are for non-leaking damaged pipe with gouges and scratches between 10-50% of the wall thickness.

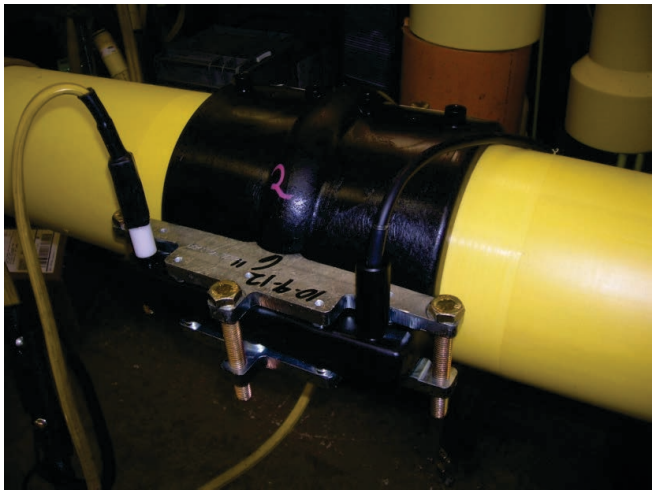


Figure 1: BFRS being installed and encircling an existing butt fusion. ElectroFusion process is similar to industry standard practices.

The basis for the BFRS and VLRS was in response to the federal regulation CFR49 Part 192.311 which states each imperfection or damage that would impair the serviceability of plastic pipe must be repaired with a suitable electrofusion sleeve or the damaged pipe must be replaced.

The BFRS is designed to fully encircle a damaged or suspect butt fusion. The repair is achieved by installing the fitting around the butt fusion with traditional electrofusion (EF) processes, fully recovering pressure retention capability. Figure 1 illustrates the BFRS installation using standard

EF processes.

The VLRS is also designed to encircle a damaged or suspect section of pipe with the added capability to interlock end-to-end for extending lateral distance along the pipe to repair any length of damaged section on the PE pipe.

The design and test basis for the BFRS and VLRS are compliant with industry standards, including:

- ASTM D2513, Standard Specification for Polyethylene (PE) Gas Pressure Pipe, Tubing, and Fittings;
- ASTM F1055, Standard Specification for Electrofusion Type Polyethylene Fittings for Outside Diameter Controlled Polyethylene and Crosslinked Polyethylene (PEX) Pipe and Tubing;
- ASTM D638, Standard Test Method for Tensile Properties of Plastic.

During the project development process, participating NYSEARCH members verified application by testing the BFRS and VLRS in laboratories and by completing field installations, Figure 2 illustrates use of the 12" BFRS to permanently repair a damaged, non-leaking HDPE gas pipe.

PROGRAM STATUS

NYSEARCH has finalized the members' needs for PE pipe repairs with the BFRS and VLRS fitting applications. The sizes that were developed reflect the needs for operational use. Table 3 illustrates the available PE pipe size repair fittings.

PE Pipe Size			NYSEARCH		NUPI				NYSEARCH	NUPI
Inch	BFRS	VLRS	Concept	Project	Design	Tooling	Testing	ASTM Cert	Demo	Commercial
11/4	X	X	2017	2018						2020
2	X	X	2015							2018
4	X	X	2000							2012
6	X	X	2000							2014
8	X		2015							2018
12	X		2015							2018

Table 3: Size range to repair PE pipe with BFRS and VLRS

NYSEARCH contracted with NUPI in Italy for the design and development of the BFRS and VLRS application. Manufacturing is also performed in Italy with distribution through NUPI Americas (with a product line of 'Elofit') at two locations domestically- Texas and South Carolina.

Figure 2: Field installation of a 12" BFRS on a HDPE low-pressure gas pipeline.

Highlights

Applying permanent PE pipe repairs with BFRS and VLRS provides:

- **Operational repair options to improve safety**
- **Cost effective PE pipe system maintenance and integrity**
- **Reduction of potential customer gas interruptions**

For more information contact:
admin@NYSEARCH.org

Cured In Place Liner (CIPL) Durability and Longevity Testing

Description: **A testing program to provide experimental data on the expected durability and longevity of the CIPL system when used in cast iron (CI) and steel pipes.**

Status: **The testing for CIPL longevity and durability for up to 100 years is complete. Residual follow-on testing of liner tensile and adhesion properties is expected to be completed in 2022.**

BENEFITS

CIPL technology is a viable pipeline renewal and replacement methodology that provides trenchless rehabilitation or replacement capability for CI and steel distribution pipes. Strong experimental data provides confidence in the durability and longevity of CIPL solutions for the natural gas industry.

BACKGROUND

CIPL's have been installed on CI and steel pipelines in natural gas distribution systems in Europe, Japan and North America over the last few decades. CIPL have been used because of their rehabilitative and renewal qualities in contrast to the higher costs, construction risks, and public inconvenience associated with conventional pipeline replacement methods, particularly in congested and difficult to access areas such as river and road crossings or urban areas. Natural gas industry operators have demonstrated significant safety and economic benefits with CIPL installations, compared to conventional replacement, in addition to reliable and safe operating histories.

CIPL is a three-component system, referred to as an elastomer-fabric-adhesive structure. The synthetic fabric jacket provides the strength characteristics for resistance to internal and external pressure, soil movement, and radial expansion. The elastomer skin provides the impermeable barrier that prevents the escape of gas. The adhesive is a two-part resin that bonds to form the composite and adheres the fabric jacket to the pipe wall. Tubes of woven polyester fabric, like a hose, saturated with thermosetting resin are inserted, pressurized to expand them, and allowed to cure in existing pipelines.

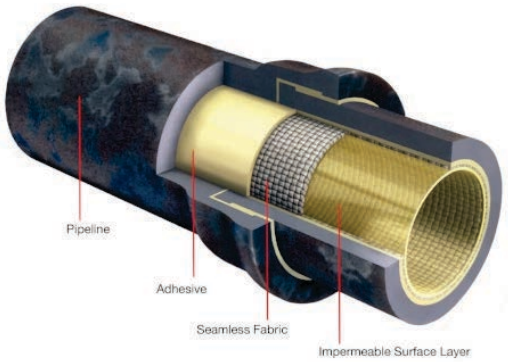


Figure 1: Cured in Place Liner System

TECHNICAL APPROACH

NYSEARCH has conducted extensive testing at Cornell University which have provided measurement data to underpin the experimental verification of the durability of CIPL system for CI and steel pipe repair, rehabilitation, and replacement. For these tests, specimens of 6-inch and 12-inch CI or steel pipe with Starline® 2000 liners were extracted from field service. Typically, these pipes had been installed at least 50 years prior and lined at least 12 years prior to the extraction. In some cases, as needed, a newly lined steel pipe was also utilized.

In 2015, NYSEARCH completed a series of tests on one set of specimens where they were subjected to 100 years of mechanical aging which included flexure testing to simulate vehicular traffic,

bending due to undermining/backfill event, and thermal contraction/expansion cycling to simulate the effects of seasonal variation in temperature. In these tests, the liner was subjected to loading at either a bell and spigot joint or at pipe joints with mechanical clamps natively present in the retrieved lined host pipe. The vehicular traffic simulations were equivalent to 2,000,000 cycles of 180-kN tandem axel load with an impact factor of 1.5, and thermal aging was performed by simulating the expected contraction/expansion of round crack in CI pipe due to a 40°F seasonal temperature (typical for the northeastern US) variation in the ground at typical pipe depths. The results of these tests noted that no leakage was detected throughout all phases of the mechanical aging tests. Pressure testing following the mechanical aging work. Again, results of these tests showed no leaks and all pipe sections maintained pressure.

Additionally, material property tests were performed to characterize the residual tensile properties of the composite liner system to assess the effects of field and mechanical aging on the liner system, as well as the residual liner/CI pipe adhesion strength to assess the durability of the bond strength using lap shear and peel tests. The results of the aged liner material properties were compared to unaged liner system properties (effectively 12 years in service + 100 years mechanically-aged) and confirmed that liner strengths were comparable between the field-aged and the mechanically aged liner specimens and that there is no evidence of significant reduction in either lap or peel strength due to the combined field and mechanical aging.

A notable finding found after visual inspection of all specimens tested in 2015 was that there was CIPL debonding discovered at the separation between the joints and the liner system. The debonding was confined to a small distance either side of the separation (less than 1 pipe diameter). This allowed the CIPL liner to stretch without experiencing excessive strain. However, in one specimen, substantial liner debonding accompanied by minor liner damage were observed. This outlier condition did not prevent the liner from maintaining the pressure boundary or leak in pressure testing. Experimental observations indicated that this distress occurred during the initial thermal loading cycle and was an artifact of the experimental setup rather than real world conditions.

Since the completion of the 2015 study, NYSEARCH has undertaken and completed (in 2019) a second study to further examine the outlier condition to ensure that thermal movements (expansion/contraction) are representative of real-world conditions. Like the original study, three lined CI pipe specimens (that indicated substantial liner debonding and some fiber damage) were again excavated and tested via thermal aging. The liner was directly subjected to loading via the host pipe bearing a circumferential break and loads applied to the pipe and liner system at that location. After the thermal cycling testing was completed, it was noted that all specimens maintained pressure and no leaks were detected. Additionally, visual inspection confirmed that liner debonding was minimal and no fiber damaged occurred.

Through a combination of work in the 1990s, 2000s, the 2015 study, and the follow up 2019 study, NYSEARCH's body of work provides extensive verification of the longevity and durability of CIPL liners for CI and steel pipe repair, rehabilitation, and replacement.

PROGRAM STATUS

The testing for CIPL longevity and durability for up to 100 years is complete. Supplementary follow-on testing of liner tensile and adhesion properties is expected to be completed in 2022.

Highlights

- Strong experimental measurement data provides confidence that CIPL systems used in CI and steel pipe renewal are assured 100 years of life under real world environmental conditions.

For more information contact:
admin@NYSEARCH.org

Northeast GAS ASSOCIATION

NYSEARCH

Technology Brief

Evaluation of Erosion Resistant Materials and Coatings for Natural Gas Lines

Description: **This project studied the effects of an underground water main leaking on nearby steel or PE gas mains and identified and tested materials that show the best resistance to erosion.**

Status: **Testing has been completed. Test results have been presented to the funding companies.**

BENEFITS

The successful completion of this project has resulted in recommendations for applying specific advanced materials of protective sleeves or coatings to transmission and/or gas distribution lines. The pipelines of interest are those where encounters with leaking or flooding water that potentially contain slurry or debris. Additionally, the performance curves, that resulted from testing and modeling, provided information for material selection to protect natural gas pipe protection, and predicted performance based on distance between the gas pipe and the water source.

BACKGROUND

In the natural gas distribution sector, there are numerous applications where natural gas pipelines are laid in parallel with distribution water lines. A breach in a water line that is close to a natural gas line has the potential to form a jet, which can erode the natural gas line to failure. For very limited situations, this failure could have catastrophic effects for nearby communities and the environment. Understanding the mechanisms behind this failure is critical to designing future pipeline systems with enhanced material durability.

In 2003, Con Edison completed a study to select the best protective solid material for applying to transmission mains adjacent to leaking water mains. That study was prompted by a compromised PriTec-coated transmission main in Con Ed territory and actions since then have been taken at Con Ed regarding protective sleeves and excavation practices.

Furthermore, the study was updated in 2017 through a NYSERACH project to include transmission lines adjacent to water lines. The first phase of this project sought advances in protective materials and distribution line applications particularly for erosion from flooding while considering other debris in water that impinges on gas distribution lines.

Figure 1: Various Protective Materials

Since 2003, there have been advances in material science that created the possibility of improved erosion resistant materials. Therefore, this experimental study was completed with eleven (11) new erosion resistant materials.

TECHNICAL APPROACH

The main objective of this project is to evaluate the effects of an underground water leaking on nearby steel or PE pipe gas mains and to generate material failure curves due to erosion based on standoff distance between the gas and water distribution pipelines, thereby allowing an estimated time to failure.

The study accomplished in 2003, and this project, had very similar test setups. This project studied eleven (11) different wrapping materials and coatings and identified the best performing erosion resistant materials. The study used a supplementary Computational Fluid Dynamics (CFD) modeling effort that determined the minimum distance at which the water distribution line and the gas distribution line could be placed in relation to each other to render the effects of the jet negligible. A negligible force was defined as the point where zero force was being applied by the fluid jet onto the gas distribution pipe.

Once the maximum standoff distance was identified, a three-dimensional CFD analysis of a slurry jet impinging on an erosion-resistant material attached to a gas distribution pipe surface was conduced on all eleven (11) materials and coatings.

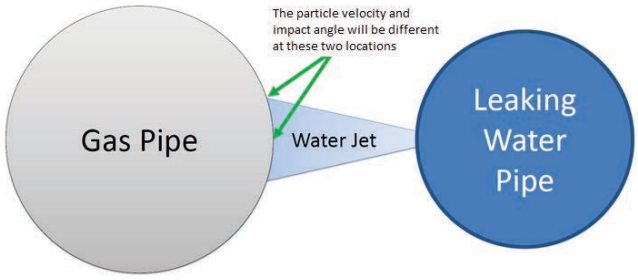


Figure 2: Jet Impingement Schematic

This analysis was conducted to determine both the erosion rate curves and performance trends for all the different erosion-resistant materials as a function of discrete water jet-to-gas distribution pipe standoff distances. The initial conditions used in this project mimicked the compromised Pri-Tek coating experienced by Con Ed.

To capture the erosion rate trend, the average erosion rates obtained from the CFD analysis were plotted as a function of standoff distance. All materials evaluated had erosion rates that linearly decreased as a function of the jet-to-gas distribution pipe standoff distance and have linear trendlines with variance values that are close to one. Using these erosion rate trends, the material performance curves were generated, indicating the time at which the evaluated material had started to erode and ended when the material was breached (meaning the pipe underneath the material was initially exposed). These trends can be used to predict the material loss due to the erosive environment in hours or days.

The results of this analysis are based on: 1) a single slurry jet exit velocity, 2) a single jet exit or source diameter, 3) one particle concentration, and 4) one particle density and size. All provide valuable information on the evaluated material erosion resistance.

PROGRAM STATUS

The completed testing and experimental modeling have resulted in recommendations for erosion resistance materials. Materials were ranked from the most erosion resistant to the least erosion resistant. A Final Report has been issued and no further work is planned.

Highlights

- Erosion-resistant material recommendations based on material testing
- Erosion rate curves and performance tends for a variety of materials and coatings

For more information contact:
admin@NYSEARCH.org

Augmented Reality Application Development

Description: **An Augmented Reality (AR) training application for the Microsoft HoloLens focused on the building of a new Meter Set Assembly (MSA) in the natural gas distribution sector and help utilities implement Remote Assist strategies.**

Status: **NYSEARCH is collaborating with an AR training vendor to build and deliver a customized MSA procedural guide for each funder on the Microsoft HoloLens 2.**

BENEFITS

Augmented Reality (AR) and Virtual Reality (VR) have swept innovation into various industries in recent years. The technology provides a creative solution to add efficiency in workflow and numerous ways to optimize business operations. AR and VR implementation have proven to increase productivity within workforces across industries.

Figure 1. Microsoft HoloLens Application Example

The potential benefits of this program are: 1) the ability to advance the timescales required to train gas operators, and 2) the potential for bringing the field experience through AR and real-time instruction into the classroom without the need to wait for or re-create the situation in a live field environment. In addition, as the next generation of gas professionals are becoming more digitally based, the 'gamification' of training using state-of-the-art technologies would have fast take-up.

BACKGROUND

The gas industry is experiencing a tremendous amount of growth. With that growth is a surge in construction activity to expand the gas pipeline network and to replace aging infrastructure. Simultaneously, retirements of personnel have expanded the need to bring in a new, younger workforce that needs a fast-paced and high degree of training and certification by various entities. This results in a need for expanding gas operator training programs and a need to innovate on methods for training.

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 a HoloLens test program is to bring 3D reality that depicts various tasks to gas company training programs. This accelerates the ability for the trainee to experience the conditions that are required for that task and to make the process for gaining knowledge more accurate and quicker.

Because Microsoft released the HoloLens device and advertised the ability for users in personal or commercial situations to develop their own applications, NYSEARCH investigated and

reported on the possibilities of using HoloLens to address one or more gas training tasks in a hands-free, heads up fashion using Augmented Reality.

TECHNICAL APPROACH

A pilot program began in 2017 to explore and evaluate the HoloLens at each gas utility funding the NYSEARCH project. Along with providing a HoloLens device and training to an individual or multiple personnel who is/are assigned at the funding company, a test plan was generated for all funders to follow and keep personnel focused on a thorough evaluation of the application(s) of interest.

Following the pilot at each funding company, feedback was collected where funders gathered ideas and preferences for gas operations training tasks at the end of testing.

NYSEARCH funders agreed to develop a more robust training experience focusing on a single gas operational task and a consensus was reached to develop a gamified training of gas leak survey and investigation procedure. Furthermore, a specific gas operational procedural task was also developed using the Microsoft 365 Dynamics program.

The specific course developed uses a 'guided discovery process' that strongly engages the learner with the importance of their work and its critical nature ensuring the safety of our customers, preservation of assets and reputation of the company. It builds confidence while teaching the standards and process.

The belief is that AR technologies will be instrumental in closing the gap that is responsible for the shortage of skilled workers. Because AR will allow more workers to do high-skill jobs, and improve their performance in this work, industrial productivity will grow. Further, due to the young age and interest with 'gamification', the newest generation of gas professionals would likely welcome with little inhibition the latest generation of technology for their training and take great interest in a job and a training program that is embracing state-of-the-art technology.

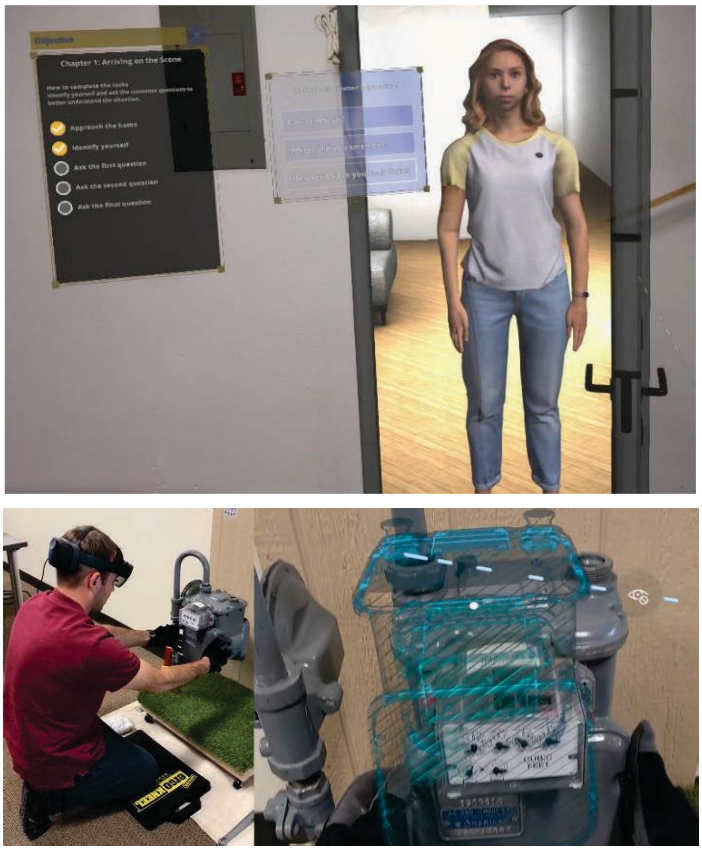


Figure 2. Developed applications for the leak investigation procedure and MSA build using Microsoft Guides

PROGRAM STATUS

Several member companies have engaged with the AR vendor to customize the Microsoft Guides to company specific MSA procedures. The strategy for implementation also includes deploying a unique function of the Microsoft HoloLens called Remote Assist where distance learning and field calls can quickly be integrated into utility operations. NYSEARCH is also evaluating and expecting to develop further applications for Augmented Reality development specific to the Microsoft HoloLens.

For more information contact:
admin@NYSEARCH.org

Machine Learning (ML)/Artificial Intelligence (AI) Proof of Concept Study for Predictive Maintenance

Description: **A feasibility study to leverage machine learning / artificial intelligence techniques with existing enterprise data for predicative maintenance in the areas of corrosion management and leak survey.**

Status: **A ML/AI guidebook has been developed and provided to the funders. Data collection and synthesis are being completed for pipe corrosion and leak survey use cases.**

BENEFITS

Successful leveraging of existing utility data with Machine Learning (ML)/Artificial Intelligence (AI) techniques will provide LDCs avenues towards predictive maintenance as an alternative to prescriptive or diagnostic analysis driven maintenance, increasing safety and reducing cost. If successfully applied, ML/AI techniques have the potential to provide significant process improvement opportunities for LDCs.

BACKGROUND

Natural gas facilities exist in a variety of environments and face equally varied levels and sources of threats. LDCs expend ever increasing efforts to ensure that these facilities are well maintained to safeguard public health and safety. Regulatory and cost driven programs necessitate prescriptive and timely monitoring and maintenance activities to mitigate failures. To support these programs, LDCs already perform sophisticated analyses of voluminous amounts of data gathered by operations, locater, leak surveyor, and close interval surveyor personnel. Recently, new machine-assisted analytical techniques have emerged which can efficiently and economically provide analytics such that resource allocation for maintenance can be predictive and prescriptive. Leveraging these ML/AI techniques have potentially tapped into advantages in both the safety improvement and cost management areas.

NYSEARCH members recognize that each utility captures and retains a significant amount of data on the composition and time domain-based condition of their facilities. Seeing the potential of ML/AI to leverage their data for predictive analytics, a feasibility project is underway.

This project aims to provide the funding LDCs a better understanding of what ML/AI techniques are, and how they can be applied, as related to the natural gas industry. The feasibility study will explore two use cases related to corrosion and leak survey. It will analyze use cases using select ML/AI techniques to provide a risk-based outlook for predictive maintenance in leak management and corrosion detection.

TECHNICAL APPROACH

The first goal of this project is familiarization of ML/AI techniques for the funding members. This is accomplished via a guidebook that describe ML/AI techniques and discuss potential gas operations applications in detail. Through member interviews and literature reviews, the primary investigator has completed the guidebook that examines the types of maintenance activities undertaken by LDCs and discusses analytical techniques which present potential application benefits for process improvement.

The second goal is to implement ML/AI analytics and demonstrate how utility enterprise data can be

harnessed to provide intelligence such that predictive maintenance can be targeted efficiently. The project is building a synthetic data model incorporating a distributed range of values underpinned by real data from the utilities. This process is performed by using ML/AI techniques.

Data was collected on distribution pipe facilities, such as diameter, material, MAOP, age, coatings, etc., to build a pipe network model. Additionally, data on historical leaks, monitoring data such a leak surveys and close interval survey were gathered as well. Thus, resulting synthetic data model is representative amalgamation of information from disparate sources within an LDC.

Utilizing this synthetic data, a predictive analytical model is being developed to demonstrate how gas operations can benefit from a holistic data driven model. A predictive model that is generated from synthetic data, will showcase the process that employs data mining and statistical techniques. It is also expected to provide performance monitoring and alerting capabilities.

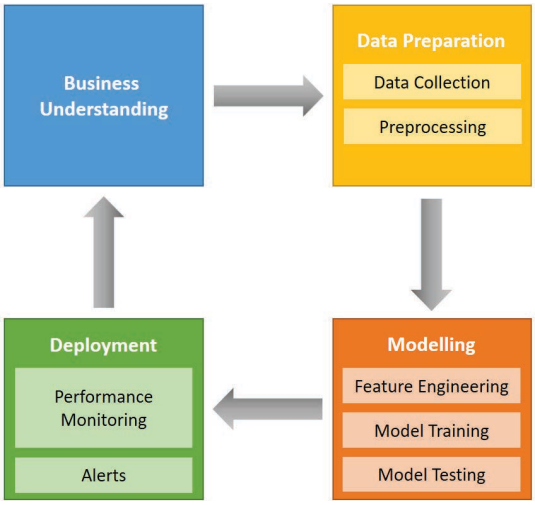


Figure 1: Data Science Lifecycle

The Final Report for this project will document the process, coding, and contextual framework on how ML/AI techniques can be used in data preparation and modelling to deploy systems that enhance decision making for leak and corrosion management.

PROGRAM STATUS

A ML/AI guidebook has been developed and provided to the funders. Data collection and synthesis are underway for the pipe corrosion and leak survey use cases. A Final Report with documented examples of ML/AI implementation for two use cases will be made available to the funders.

Highlights

- A feasibility study to leverage LDC enterprise data for predictive maintenance.
- The project explores the use of Machine Learning / Artificial Intelligence techniques for process improvements in maintenance activities.
- The project seeks to leverage existing data to predictively target specific maintenance activities for the most impact to enhance safety.

For more information contact:
admin@NYSEARCH.org

Pipe Location

Northeast GAS ASSOCIATION

NYSEARCH

Technology Brief

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 tasks are complete. Manufacturing of the tag laying machine and RFID housing 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 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 chip can operate without a dedicated power source, drawing energy necessary from the reader antenna to transmit and receive data. Information from the chip 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 chip design enables operators to accurately identify the location of pipes by using three 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.

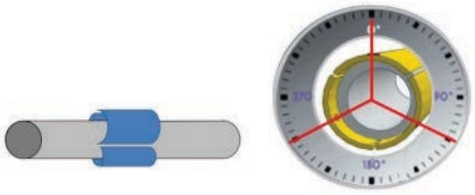


Figure 1: Three RFID Tags for 360° Coverage

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 flexible enough to be wrapped around the outside of the extruded PE pipe. These RFID tags in the soft PVC housing will be installed simultaneously with the manufacturing of the PE pipe.

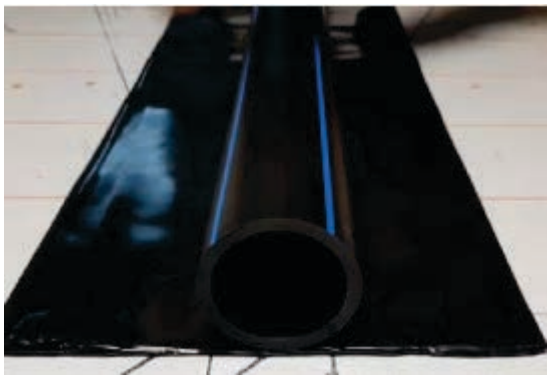


Figure 3: Soft PVC Housing Prototype

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

The machine is designed to store enough RFID housings to install a tag every 20 meters (65 feet) for over 800 meters (approximately 900 yards) which is more than the amount of pipe stored on a single drum before the RFID housings needed to be manually replenished.

PROGRAM STATUS

The documentation specifies the tag performance requirements as well as specifications to implement the tag during the extrusion process. This document has been completed.

The manufacturing of the tag laying machine has been the project focus in recent months. In parallel, with the manufacturing of the tag laying machine, NYSEARCH and GRTgaz have partnered with a pipe manufacturer in the US to integrate the tag laying machine into its production line. Horizontal Directional Drilling field tests with this technology are planned in both the France and in the United States.

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

For more information contact:
admin@NYSEARCH.org

Low Carbon Fuels

Northeast GAS ASSOCIATION
NYSEARCH

Technology Brief

Scaling of Microbial Power to Gas Conversion for Long Term Operation

Description: **Optimization of biological and chemical processes in the intermittent operation (periods of electron starvation) of microbial electromethanogenesis for power-to-gas operations**

Status: **Bioreactors have been successfully set up for laboratory testing and monitoring. Evaluating several biochemical properties of the active microbes during intermittent operation is ongoing.**

BENEFITS

As the natural gas industry is beginning to see a shift towards decarbonization, NYSEARCH has 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. 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. This research addresses for the first time the molecular, cellular and metabolic processes associated with a long-term operation of an electromethanogenic system; converting electrical energy plus CO_2 into methane at high rates. Furthermore, 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.

BACKGROUND

The development of new ways to store excess electrical energy and produce carbon-neutral biofuels is key to mitigating global climate change and developing a more sustainable society. Electricity, in particular electricity produced from renewables, is becoming a more abundant and common resource. However, electricity produced from renewables is intermittent and is inevitably lost when not used following production. A viable and long-term solution to store this excess renewable energy is needed. 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. Hydrogen, alone, is not an ideal chemical storage compound with low energy density and significant safety concerns for its use.

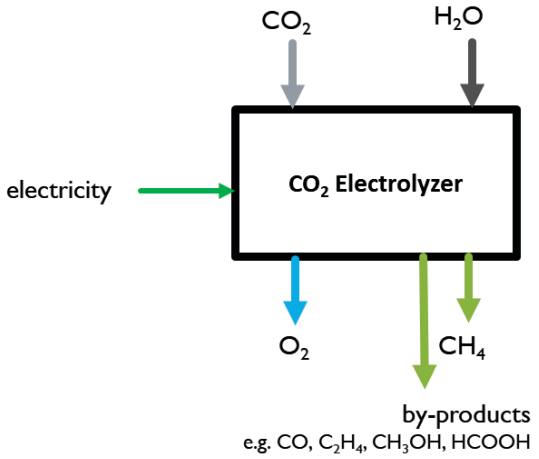


Figure 1. Traditional Power to Gas (P2G) process

Microbial electrosynthesis is emerging as a viable technology platform for converting electrical energy into natural gas by microbial 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.

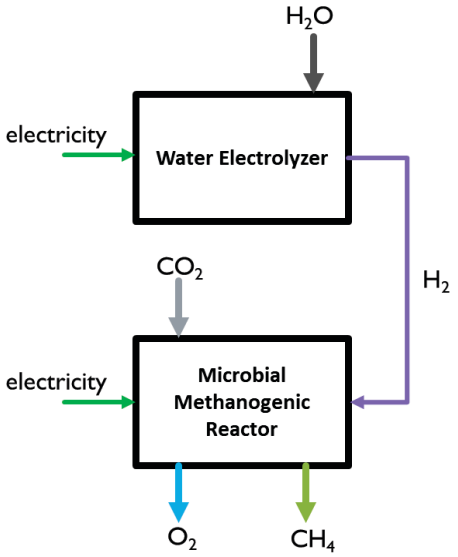


Figure 2. SOA microbial P2G process

The basis of this project explores Stanford University's innovation where microbial electrosynthesis uses CO_2 as a substrate with a cathode created from low-cost sustainable metals and direct consumption of the produced hydrogen, 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. Figure 3 summarizes this electromethanogenesis process.

TECHNICAL APPROACH

Stanford University's recent work on microbial electromethanogenesis 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 enhances the conversion rate from power to gas.

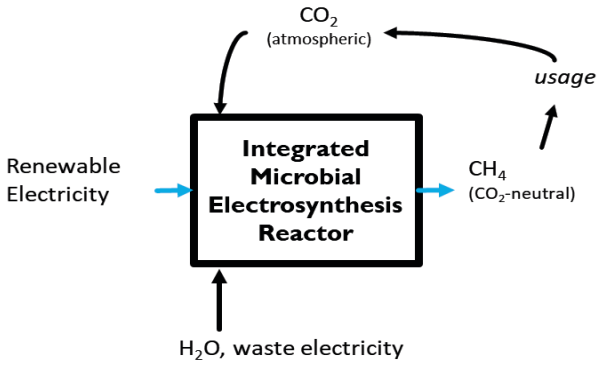


Figure 3. Integrated electromethanogenesis process

NYSEARCH and Stanford are working to better understand the long-term effects that the microbes experience as living agents of electrochemical reactors. Specifically, this phase of research focuses on the response of the microbes to physical and chemical changes associated with intermittent operation of an integrated bio-electrochemical reactor. Stanford is investigating factors impacting performance during electron starvation (intermittency) such as microbial viability and longevity, recovery rate during intermittency, and cell protein expression.

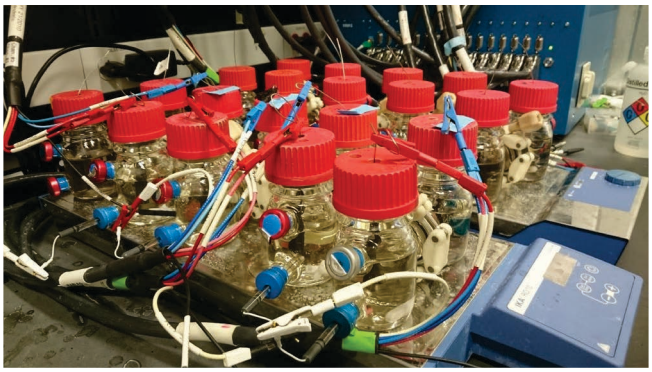


Figure 4. Laboratory set-up of electrochemical reactors prepared for long-term operation

PROGRAM STATUS

The research team is inoculating and testing the bioreactors under predictable and unpredictable intermittent patterns to evaluate microbial performance. With information on the chemical and biological changes associated with intermittency, NYSEARCH and Stanford are poised to develop an engineering prototype that is scalable for industry power-to-gas operations.

For more information contact:
admin@NYSEARCH.org

Northeast GAS ASSOCIATION
NYSEARCH

Technology Brief

Assessment of Consequences of Renewable Natural Gas (RNG) on Gas Infrastructure & Appliances

Description: **State of the art assessment for risks associated with biomethane injection impacting distribution gas networks and downstream appliances**
Status: **Risk Assessment Complete**

BENEFITS

The benefits of this study are to: 1) leverage similar work done in Europe and in the Nordic countries, and 2) take actions that are necessary to protect our pipeline networks and our customers appliances for the higher risk areas associated with constituents of Renewable Natural gas (RNG) when processed through the gas network. These actions may require additional work. The project serves as a platform for an RNG roadmap and it identifies technology gaps.

DNV-GL has extensive experience from working with gas company consortia (such as GERG), individual gas companies (NGrid UK), regulatory agencies (UK Health and Safety Executive) and other organizations that are more advanced in implementation of RNG systems. They have examined the impacts of different forms of RNG to the infrastructure and to customer appliances. A combination of effects is being evaluated. Lessons learned from cases in Europe show that some regulations may be too constricting and unnecessary.

BACKGROUND

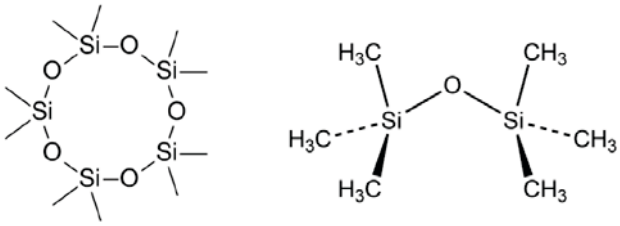
NYSEARCH members have shown a strong interest in stepping up activities in the area of developing opportunities and understanding work for implementation of RNG and in de-carbonization. In late 2017, NYSEARCH Staff was asked to investigate what technology gaps exist and to work with the committee in defining an R & D roadmap.

RNG is considered gas that is fully interchangeable with pipeline quality natural gas. Sources of RNG such as biogas, syngas, blended hydrogen in natural gas and power-to-gas (using renewable electricity) are not all at the same stage of development. The benefits to the regulated LDC community are to expand its understanding and reach in implementing various forms of RNG related to offsetting the use of natural gas (to reduce GHG emissions) while leveraging the existing gas network. Also, this customer-friendly energy approach makes use of the local resources and adds diversity of supply.

With a State-of-the-Art Technology Assessment project in mind, NYSEARCH Staff identified DNV-GL as a collective corporation that merges R & D work and project consultancy in Europe and N. America with expertise in risk assessment for European gas companies and for N. America.

TECHNICAL APPROACH

The objective of the project is to assimilate past research that taps into a wealth of knowledge on potential risks of RNG and combine that knowledge with a study of differences and similarities to North American gas LDC conditions. This approach provided two risk assessments specific to North American gas network conditions on individual constituents and combinations of constituents for selected LDC pipeline environments.



D5: Decamethylcyclopentasiloxane L2: Hexamethyldisiloxane

Figure 1: Types of siloxanes found in biogas

The work focused in two areas to examine risk: 1) impact of Siloxanes (see Fig. 1) on gas appliances and engines, and, 2) impact of corrosive substances on materials in the LDC gas network (and potentially downstream appliances). It is envisioned that with □risk ratings□ in these two areas, recommendations can be made regarding technology or regulatory gaps that exist or whether and how interconnect guidelines and/or regulations should be interpreted.

Likelihood	Impact on Network and/or Appliances
0: Not credible	0: Zero impact
1: Low Less than annual event	1: Minor financial impact
2: Medium 1-6 events per year	2: Medium financial impact
3: High Monthly/Weekly/Daily	3: Major financial impact

Figure 2: Risk Assessment Methodology

Both efforts required input by our funding members on their pipe systems and feedstocks/biogas or other sources to study. DNV-GL used this information and then factored in how the North American systems are different (pressure, operating environments, cleanup processes and other factors). DNV-GL lead the effort on highlighting what substances to consider (e.g. H2S, inerts, microorganisms) and then considered both steel and plastic pipe networks as well as gas appliances to provide risk impact ratings (See Fig. 2). Also, they addressed □likelihood ratings□ to determine an overall risk rating.

PROGRAM STATUS

The impacts of each corrosive substance on the wide range of materials found in US gas networks and US gas appliances have been discussed in the Final Report. This includes the impacts of combinations of substances and gas types considering US Gas Delivery Specifications on water, hydrogen sulfide, oxygen and carbon dioxide and network operating conditions.

This comparison has identified a number of regulatory gaps or deficiencies and, where required, recommendations for improved regulations are made. Conversely, suggestions have been made where current regulations could be relaxed; these suggestions have been based on DNV-GL□sUK and European experience.

The risks associated with siloxanes in RNG to residential appliances and engines are assessed in the Final Report. The results obtained from testing of oxygen sensors and catalysts used in heavy duty and light duty vehicle engines can be used as input for developing specifications in the US that provided differences in overall gas usage and/or maintenance regimes are accounted for.

In case of identical appliances, results were directly translated from European testing for siloxane impact. As in case of heat exchanger, where design is significantly different, it is recommended that actual testing be carried as the siloxane dose-effect on appliance relationships observed are typically non-linear.

Highlights

- Indicative likelihood and impact ratings have been determined for individual substances in RNG.
- Recommendations to reduce risk and improve safety have been made.

For more information contact:
admin@NYSEARCH.org

Testing of Residential Appliances for Impact of Siloxanes

Description: **Practical testing to evaluate effect of Siloxanes on residential appliances' performance**
Status: **Appliance testing produced initial results; additional testing ongoing.**

BENEFITS

This project aims to address the ongoing dialogue on the technical limits of siloxanes in Renewable Natural Gas (RNG). Assessment of siloxane impacts on sensitive natural gas end-use equipment will help to specify technically-sound limits. The largest impediment for translating results obtained from available literature is that a majority of in-use appliances are designed differently from those that have been previously studied. Additional testing will help us reduce the uncertainties by providing scientific data to support siloxane 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 determine the optimum upgrading and measurement system for siloxanes in biomethane.

BACKGROUND

To reduce carbon emissions and to move towards a more sustainable energy supply, there is an increasing trend of using RNG in the United States and Canada. Depending on the source, RNG can contain compounds that are not present in traditionally distributed natural gas such as siloxanes (See Figure 1). Siloxanes are man-made organo-silicon compounds found in a wide range of consumer products such as detergents, shampoos, cosmetics, paper coatings and textiles. These products can find their way to biogas feedstock such as wastewater sludge, landfills etc.

NYSEARCH conducted two studies, one of which was a Risk assessment of the effects of Siloxanes on residential gas appliances and gas engines by DNV-GL. It was based on an experimental evaluation of siloxane impacts on multiple residential appliances that was recently conducted in Europe. The study concluded that there were a few major differences in the appliances between Europe and North America, mainly the absence of an air-fuel ratio and controller, presence of thermocouples in appliance and different heat exchanger configurations (and materials). These differences can have a significant impact on acceptable siloxane limits for these appliances. Hence, it was recommended that an inventory of appliances be taken in NYSEARCH member areas and a measurement program be developed for tests on these appliances to identify and quantify their failure modes.

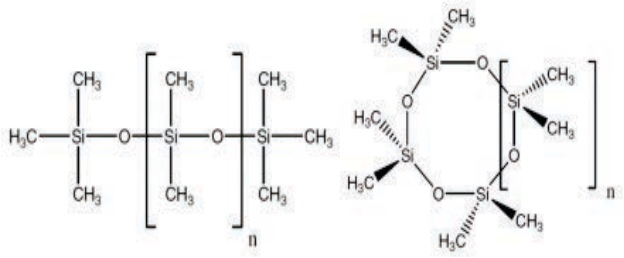


Figure 1: Repeating structural units for Linear (Left) and Cyclic (Right) Siloxanes

TECHNICAL APPROACH

The objective of the project is to determine the maximum concentration of silicon-containing molecules (See Fig. 1) in RNG that will preclude significant safety, reliability, performance, and maintenance impacts for US and Canadian residential appliances. The first step was to develop a Test Plan. Published results were reviewed from the residential appliance tests in which the impacts

of siloxanes were evaluated including the (2) NYSEARCH studies completed in 2019. Discussions were held with research organizations that have conducted these tests (e.g., DNV, University of Southern California) focusing on test protocol, specialized laboratory equipment, and siloxane impacts on appliances. Of significant interest were appliance characteristics that result in sensitivity to silica deposits (e.g., heat exchanger geometry, heat exchanger materials, and flame sensor position) and the equipment utilized by these organizations to accurately blend low concentrations of siloxanes into natural gas.

The next step was to carry out the appliance testing. Testing is taking place in two rounds. In Round 1, about (8) appliances were setup in Primaira's laboratory (See Fig. 2), located in Woburn MA. Gas, electrical, water, and venting connections were secured and the siloxane blending system was integrated into the gas piping. The siloxane system consists of several vessels containing liquid siloxanes (e.g., D5).

Figure 2: Test Setup at Primaira Lab

Pressure, temperature, and flow rate controls enable accurate setting of the concentration of siloxane in natural gas. The siloxane dispension system was rented from DNV-GL in the UK. Based on the Round 1 results, appliances that are found to be sensitive to siloxane impacts, are to beselected for testing at a lower siloxane concentration, in Round 2. New or replacement appliances are also being acquired, and baseline performance testing is being conducted.

At the conclusion of testing in Rounds 1 and 2, the results for each appliance are also being analyzed to estimate the maximum siloxane concentration that would prevent the observed failure mode from occurring over that appliance's expected service life. By combining results for all the appliances tested, we will determine the maximum siloxane concentration that is expected to be acceptable for the US and Canadian residential appliance population.

PROGRAM STATUS

Test planning has been completed. Sensitive appliances were selected based on Expert advice and input from NYSEARCH project sponsor(s). Baseline appliance testing was carried out to ensure the setup for the siloxane delivery system works well. Round 1 testing for high siloxane concentration (~12 mg/Si m^3) has been completed and failure modes are being analyzed. The results have been shared with the project SME's and a list of appliances have been proposed for Round 2 (low Si concentration) testing. At the end of Round two testing, we will have two data points to extrapolate the results for the lifetime per gas usage of the appliances.

For more information contact:
admin@NYSEARCH.org

Northeast GAS ASSOCIATION NYSEARCH

Technology Brief

Identification and Development of an Analyzer for Siloxane Measurement

Description: **State of the art assessment for identification of a portable siloxane analyzer technology that meets NYSERACH sponsor(s) specification**

Status: **In Phase II of the project, shortlisted analyzers are being evaluated through lab and field testing in North America**

BENEFITS

The benefit of this study is to leverage expertise of gas research centers of excellence in Europe by conducting an expansive search for a siloxane measurement tool. The approach will allow us to understand the technical requirements and solutions that are necessary to quantify the presence of siloxanes in Renewable Natural Gas (RNG)

The program could result in a future solution necessary to qualify a biogas clean-up facility as acceptable and to bring data to the discussion about reasonable limits/ methods for addressing trace levels of siloxanes in specific RNG applications.

BACKGROUND

NYSEARCH has been discussing several needs related to de-carbonization and potential challenges to implementation of Renewal Natural Gas (RNG) using our members existing LDC infrastructure. Gas quality questions arise regarding trace constituents from various sources of RNG.

In recent years, scientific groups such as the California Council on Science and Technology have done literature search and other work to understand what levels and measurement thresholds should exist for different constituents in processed biogas. In the case of biogas that is produced from wastewater and landfills, where household agents come into play, siloxanes [family of man-made compounds consisting of silicon and oxygen (See Figure 1)] have been found that may carry forward minute quantities to processed biomethane after processing. Siloxanes are used in anti-foaming agents, fire retardants and consumer products such as deodorants and shampoos]

GRT Gaz/RICE and others in Europe have also studied the impacts of trace constituents and now refer to a standard in Europe known as EN-16723-1 that has adopted a maximum value for siloxanes. Research organizations, including NYSEARCH, have attempted to develop a sensor that can measure siloxanes at very minute (ppb) concentrations. An unsuccessful attempt to measure siloxanes was made as part of an advanced chemical sensor project at NYSEARCH. With that technology, we used nano-sensor technology that worked for an array of chemicals but not siloxanes. Reports by GRT Gaz and others indicate that there still is an open need for a reliable tool for siloxane measurement. Thus, it was proposed to work within the European scientific community and use the resources that GRT Gaz/RICE have to find a tool that would meet LDC's specifications for siloxane measurement.

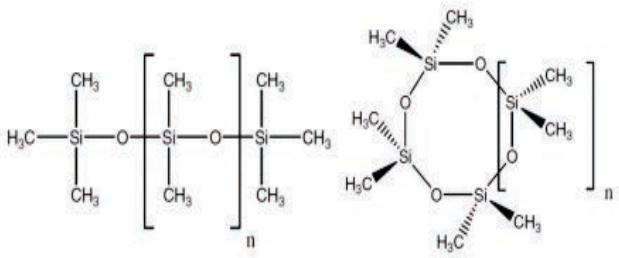


Figure 1: Repeating structural units for Linear (Left) and Cyclic (Right) Siloxanes

TECHNICAL APPROACH

The objectives of the project are to identify a suitable technology, technology provider and workplan to develop a siloxane tool, preferably portable, that can measure concentrations of siloxanes at regulated threshold levels (as low as 0.1 mg Si/m3). A subsequent program objective is to work collaboratively with other gas company users and developers who are implementing RNG plants to use the developed tool to inform ourselves and others about the presence of siloxanes in equipment that use RNG and to ultimately use that information to develop a practical standard for acceptable levels of siloxanes.

GRT Gaz, who is the main Transmission System Operator (TSO) in France with over 20,000 miles of transmission main, is counting on its Innovation Department, RICE, to address the same needs that our members, who are active or interested in getting active in implementation of RNG have expressed. RICE also works with other European research agencies such as GERG, DNV and others. RICE and its partners in France have spent considerable time in the RNG arena to understand State-of-the-Art technologies because of the growing use of RNG in France with (49) RNG sites in service on the distribution network, (4) in the transmission network and (30) more expected by the end of 2018.

Figure 2: Sample Portable siloxane Analyzer

In this first effort, we worked with NYSEARCH funding members in a stepwise process to set technical specifications. RICE then researched what is available in state-of-the-art technology and how that applied to NYSEARCH specifications. In the final step, an assessment (with the involvement of our funders) was performed of the various analyzers identified and the most promising technologies selected for a siloxane tool. Data was collected to justify the 'Technology Readiness Level (TRL)' and the pros and cons of the different solutions.

PROGRAM STATUS

The State-of-art (SOA) assessment has been completed and the shortlisted analyzers have been presented to the project sponsor(s) for their review. A next phase has been launched to evaluate these analyzers further through laboratory and field testing. The final goal is to help reduce the list of suitable technologies for siloxane measurement and to define the anticipated work and time necessary to fully apply/develop the tool.

For more information contact:
admin@NYSEARCH.org

Study on Impact of Trace Constituents in RNG

Description: **Gap analysis followed by practical testing to evaluate effects of trace constituents in RNG on gas infrastructure and residential appliances**

Status: **Gap analysis ongoing to identify trace constituents, trigger limits and scientific evidence to support specified limits**

BENEFITS

This project aims to reduce the uncertainties and variation in limits set by different utilities for the trace constituents in Renewable Natural Gas (RNG) by providing scientific data to back up the trigger limit recommendations. In light of 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. Accelerated testing will be conducted to evaluate safety limits for each of them.

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. DNV-GL is also currently in the

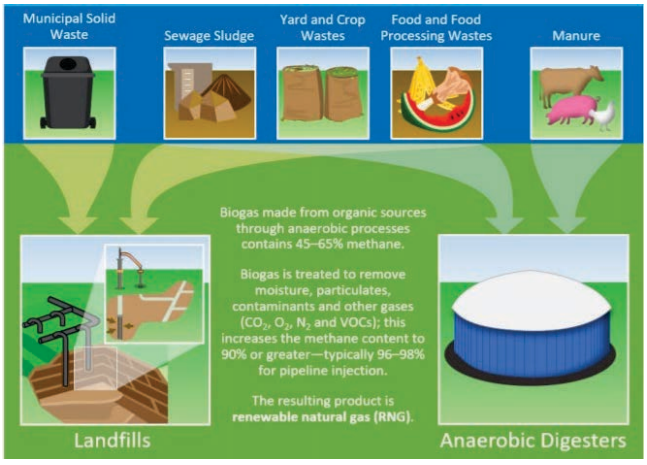


Figure 1: RNG Sources and trace constituents

process of testing for Trace Constituents for gas 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 is 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 is assembling 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 is going to also include 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 is being conducted for consumer appliances as part of Task 1. The result is a list of trace constituents that are believed to be damaging and those trace constituents or combination of trace constituents that cause problems during or after combustion.

Figure 2: Experimental Accelerated testing in lab

DNV-GL will recommend to NYSEARCH 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. The combined output allows NYSEARCH sponsor(s) to carry out a fully informed assessment of which contaminant or group of contaminants need further testing.

Task 2: Experimental Test Program: The test program (see Figure 2) is anticipated to use an optimized fractional factorial experimental 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 would be 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 is working on the gap analysis and will propose a list of trace constituents that need experimental testing to sponsoring utilities. Based on DNV-GL's recommendations and consensus among NYSEARCH sponsors, the list will be prioritized for further testing in 2021.

For more information contact:
admin@NYSEARCH.org

Northeast GAS ASSOCIATION
NYSEARCH

Technology Brief

Living Lab for Biomethane (RNG) Assessment

Description: **A five-year controlled study to assess impact of processed biomethane on gas distribution infrastructure.**
Status: **Test material has been installed for the Living Lab at Newton Creek and the Twin site. Commissioning of the biomethane recovery system is pending.**

BENEFITS

The planned Newtown Creek wastewater treatment biomethane recovery system offers National Grid and the industry at large a unique opportunity to monitor the immediate and long-term impacts of direct injection of biomethane into a local distribution network via a "living laboratory" environment. The relationship of gas processing technology, monitoring instrumentation and downstream piping system impacts will be explored to help fill long standing industry wide knowledge gaps. This integrated practical operations approach to assessing potential infrastructure impacts, coupled with the bench scale laboratory bench scale testing will help develop a long-term strategy to embrace this valuable renewable energy resource.

The comprehensive five-year research initiative will identify the levels and nature of trace constituents (such as siloxanes, sulfur, CO_2 etc.) of interest in processed biomethane. Also, a duplicate test system operating on traditional pipeline quality gas is being constructed from the ground up based on input from subject matter experts. This will help create an exclusive data set to evaluate specific pipeline components at the material level.

BACKGROUND

NYSEARCH has been considering not only existing projects that support RNG and what is now referred to by some as 'decarbonization' but looking to address Technology Gaps specifically in terms of impacts to the gas infrastructure and gas customers. Of the technologies and processes that are possible for conversion and use as RNG, the most advanced and used approach is through the same process selected in the Newtown facility, that of anaerobic digestion of waste.

Figure 1: Newton Creek Wastewater treatment facility and Biogas Digesters

The commercial digester (see Figure 1) in this project is owned by the NY Department of Environmental Protection (DEP)/City of New York. There is a tight collaboration between DEP and National Grid on the design of this pressure swing adsorption clean-up system that is intended to process between 550 MMCF – 800 MMCF of raw biogas per year. This processing will amount to 277,500 – 377,500 MMBtu of pipeline quality gas per year

that will be directly injected and blended into National Grid's distribution system.

TECHNICAL APPROACH

The objectives of the project are to: a) study the impact to gas infrastructure of processed biogas from the Newtown Creek wastewater treatment facility, and, b) compare information from this system to a pipeline system specifically designed to be equivalent but with utilization of traditional pipeline quality natural gas. The study is design to evaluate and compare immediate impacts and impacts over time from first startup through five years of operation.

Figure 2: Installation of Living Lab test setup

The sampling plan will identify the levels and nature of trace constituents within the RNG (or biomethane) in both real time and based on agreed periodic sampling and lab analysis. These include hydrocarbons, VOCs/SVOCs, O_2, CO_2 and other inerts, and general H_2S levels. Also, various pipe materials will be included in the piping system (See Figure 1) so that they can be extracted and analyzed. The same analysis will be performed at the parallel site at a National Grid property in Long Island (operating with the traditional pipeline quality gas) that will be constructed with the same materials and lots so that a direct comparison can be made based on the project's test plan. Analyzers for moisture and trace constituents, metering and other instruments are included. Materials to test will be located at the outlet of the meter but prior to the flow into the 60-psi distribution system. Planned system materials include PE pipe segments, steel pipe segments, common gaskets and couplings, and fittings.

PROGRAM STATUS

Newtown Creek is the largest of its kind in North America and located in the City of New York. Some of the activities to date included multiple reviews by various NYC agencies (NYC, FDNY, EPA, etc.) of the design. The setup for Living Lab (See Figure 2) has been installed at Newtown Creek and the alternate "twin" site that would see typical natural gas. Construction of the clean-up facility (See Figure 1) is complete. The testing for commissioning is in progress.

Highlights

- Assess RNG impacts on the gas infrastructure over a long period of continuous operation
- Ability to Compare two systems – flowing RNG and traditional gas designed with material from same batch

For more information contact:
admin@NYSEARCH.org

Northeast GAS ASSOCIATION NYSEARCH

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 is performing 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 aims 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.

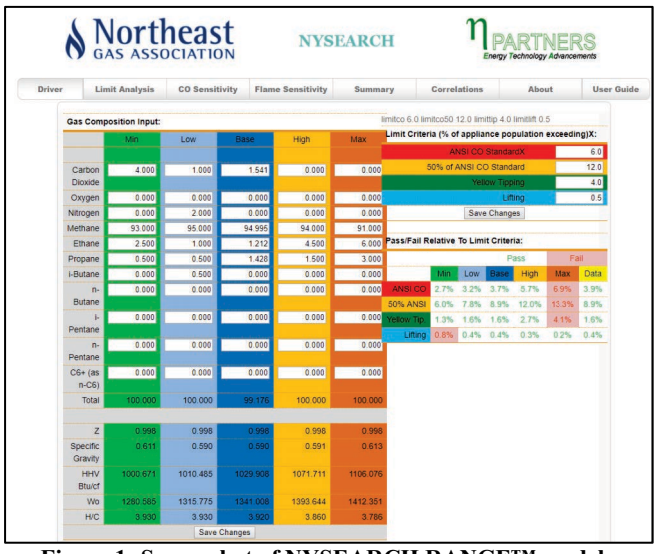


Figure 1: Screenshot of NYSEARCH RANGE™ model

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

address the ongoing dialogue and the technical limits of siloxanes in Renewable Natural Gas.

TECHNICAL APPROACH

The objectives of the project were to improve the ability of the NYSEARCH RANGE™ model by: a) establishing interchangeability boundaries for bio-derived Renewable Natural Gas by characterizing flame lifting, b) determining appliance performance with Hydrogen blends to establish interchangeability boundaries for Power-to-Gas RNG and, c) specifying a concentration limit for silicon-containing molecules in RNG that will preclude significant performance and maintenance impacts for end use equipment.

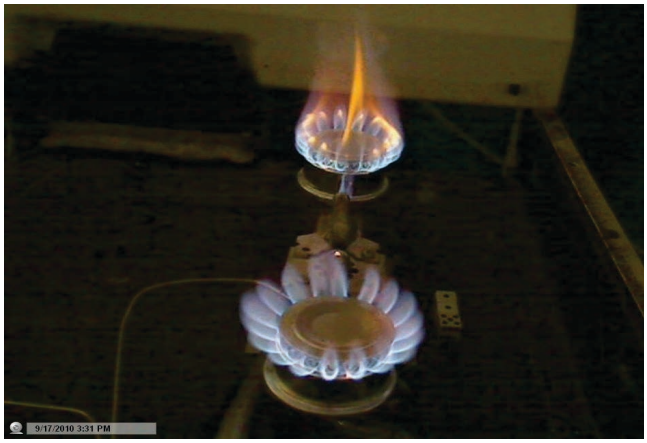


Figure 2: Stove-top Flame Variations with Wide-Ranging Settings.

Detailed appliance tests were conducted at each of the service training labs at the two participating LDCs. The impact of gas quality on the performance of each appliance was tested using the local gas supply and three defined RNG gas compositions. Effect of different appliance adjustments was also evaluated. As part of the testing, flue gas carbon monoxide and oxygen concentrations were measured. Also, flame appearance was characterized using the AGA flame code, and photos of the flames taken (See Figure 2). The merits of incorporating either a new flashback correlation or variations of the Weaver and AGA flashback indices into the model was evaluated and the best approach selected.

For the 3rd task, Eta Partners reviewed the California Council on Science and Technology report on siloxane limits and other relevant literature. They defined specific equipment impacts and determined the basis for fuel specification siloxane limits by literature review as well as interviewing Subject Matter Experts (SMEs) at the manufacturing companies. This helped identify any additional testing or monitoring needs. Based on these findings, an interim limit (expressed as mg silicon/nm^3) for siloxanes in RNG has been recommended.

PROGRAM STATUS

Appliance testing (See Figure 3) has been completed at NYSEARCH LDC member laboratories. Based on the test results, flame lifting, and flashback correlations have been incorporated into the NYSEARCH RANGE™ model. The new model has been verified by comparing predicted performance to results from the current and prior tests.

The new and improved NYSEARCH Range™ *Plus* model that can define Interchangeability for RNG is available for purchase for non-members on the NYSEARCH website; www.nysearch.org.

Figure 3: Testing at an LDC lab

For more information contact:
admin@NYSEARCH.org

Northeast GAS ASSOCIATION
NYSEARCH

Technology Brief

Hydrogen Blend Impact on Elastomer Materials

Description: **Multiple phase project to understand how the physical properties of elastomers will change when introduced to a hydrogen and natural gas blend.**

Status: **Laboratory testing of SBR and NBR materials against varying gas compositions is ongoing.**

BENEFITS

The results of the testing will be put together detailing the response from the set of elastomeric materials under limited operating conditions to the presence of hydrogen. The Final Report will document the actual test data results, analysis, discussions, and conclusions leading to the summary matrix/table so that utilities can better understand how materials will react with the presence of hydrogen in the natural gas pipeline.

BACKGROUND

As gas supply in the United States gets increasingly diversified, the composition of the gas delivered through the distribution network to the end user is experiencing an increasingly greater variation. Distribution system components and end-use equipment have been designed and operated over the last decades based on a well-defined gas composition. Thus, the concern emerges regarding the impact of these diverse compositions on various parts of the existing LDC infrastructure.

From 2005 to 2016, NYSEARCH members funded a Gas Technology Institute (GTI) study to determine the effects of gas interchangeability on components carrying elastomeric materials of the infrastructure such as couplings and diaphragms. Additionally, it determined the effects of mechanical properties on elastomeric materials under various pressure and temperature conditions. The impact of the higher order hydrocarbons found in natural gas was studied systematically.

Results showed that the gas composition has a lesser effect on restrained couplings than a change in temperature. For the field-extracted restrained couplings, the low temperature was the dominating factor for observed leaks and lean gas was the secondary contributor.

As hydrogen/natural gas blends are being considered as an alternate fuel to be distributed through the existing natural gas infrastructure, there is a need to understand the performance of elastomeric materials in the presence of hydrogen.

TECHNICAL APPROACH

The objective of this project with GTI is to determine if blending hydrogen into a fuel gas will change the physical properties of elastomers used as materials of construction in a natural gas delivery system.

This project is designed to have multiple phases. Currently, two phases are in discussion. The first phase is a set of exploratory tests using a limited set of test gases on virgin Styrene-butadiene Rubber (SBR) and Nitrile-butadiene Rubber (NBR) elastomeric coupling materials. The data obtained in Phase I is being used to inform additional testing needs for a Phase II effort. Phase II is further developing the information obtained in Phase I by performing tests on field-extracted and virgin materials using an expanded set of test gases.

The first task of Phase I was to determine the time to saturation for hydrogen exposure for the selected test gases. Small test coupons were cut from the virgin coupling using a die cutter. This device is designed to keep all the sides of the coupons as parallel as possible, minimizing data variables.

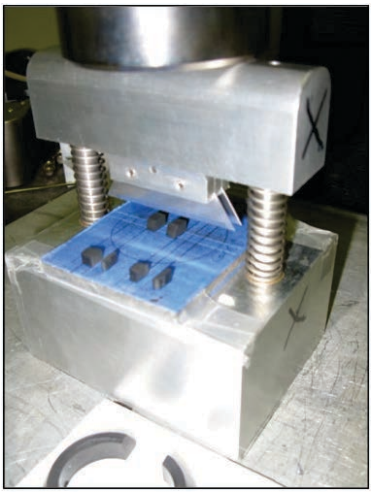


Figure 1: Die Cutting Machine

The exposure experiments were carried out at ambient laboratory temperature conditions and at a set pressure, under trickle flowing gas using a high-pressure test chamber. Figure 2 shows the stainless steel five level rack holding the coupons and the fully assembled pressure vessel.

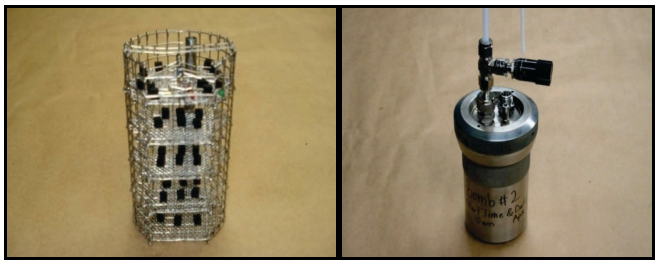


Figure 2: Coupon Test Vessel

The coupons were placed in this vessel and removed after specified times of the gas exposure and placed into a headspace vial for subsequent analysis where the hydrogen concentration was plotted versus the time to construct the saturation curve.

After the time to saturation was determined, additional specimens of the virgin materials were cut and subjected to further testing performed in a thermomechanical analyzer. This instrument performed (4) four tests: shrinking (dimensional change as temperature is lowered), swelling (dimensional change as temperature is raised), creep (change in dimension at constant force over a defined test period), and stress relaxation (change in load under constant displacement over a defined test period). The goal is to determine hydrogen impact on the elastomer.

PROGRAM STATUS

In the preliminary analysis of Phase I testing the results showed the SBR elastomers deformed less when exposed to hydrogen, which was not surprising due to the softness of SBR elastomers. All of the testing is completed which includes baseline testing of specimens not exposed to a hydrogen blend and specimens exposed to 5% and 20% hydrogen blend. The results are being compiled into a report that will also provide the data in a reduced test summary matrix.

Based on the summary of results from Phase I, funders are deciding on the Phase II tasks. The scope and extent of the Phase II work is to be determined based on number of vintage materials and gases tested.

Highlights

- Assess impacts of Hydrogen/Natural Gas blends on LDC infrastructure.
- Hydrogen/Natural Gas is considered an alternative fuel source.

For more information contact:
admin@NYSEARCH.org

Leak Detection

Natural Gas Dispersion Study

Description: **An experimental and numerical study of methane dispersion to help determine the optimal placement of methane detectors in residential settings. This effort will aid the ongoing effort to create a NFPA standard and update UL 1484.**

Status: **Phase II complete with assessment of impact of mechanical and natural ventilation**

BENEFITS

As the natural gas industry promotes the use of methane detectors, several issues need to be addressed. Two of these issues are: (a) the proper placement of these detectors in a residence, and (b) the gas concentration at which the detector should alarm. To be able to address these issues, detailed data regarding the dispersion of methane under various conditions and in various layouts is needed. This study will provide us with such data through actual monitoring of different structures (See Fig. 1)

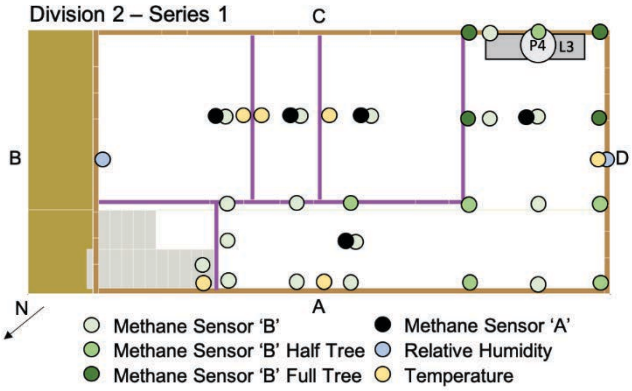


Figure 1: Residential test layout with sensor trees

The program is also validating a model to simulate such phenomena. The present state of the art in models simulating dispersion of methane in air under near-zero flow conditions does not allow for accurate simulation of laminar and turbulent flows. This study allows us to calibrate dispersion models to obtain increased accuracy. Improved modeling also allows better simulations of other layouts and scenarios. This unique study provides a benchmark for any additional studies that may be needed in the future.

BACKGROUND

The use of methane detectors in homes has emerged as a major issue for the industry, as safety concerns occupy public and regulators alike. Methane detectors are mandated by some jurisdictions and others are anticipated to follow. In addition, there is a need to formulate a Standard for the installation of methane detectors. In May 2018, NGA and Consolidated Edison were successful in gaining support from the AGA Building, Equipment, Codes and Standards Committee (BECs) for advancing an effort to develop such a standard with the National Fire Protection Agency (NFPA). However, to fully advance such a Standard, information is necessary on various elements of residential methane detection including ideal placement of the detector.

In addition, the industry, including NYSEARCH member companies, have taken an active role in promoting new methane detector technology as well as the revision of existing UL standard to improve the deployment of these detectors. Notably, the only study about dispersion of methane in homes is a British study from the late 1990s. While several layouts were studied under various gas release and infiltration scenarios, the data is limited.

Current standards require detectors to sound an alarm when concentrations reach 25% of the Lower Explosive Limit (LEL). Lowering this limit is a way of increasing safety. Given the temporal and spatial data gathered through experimental testing in a residence and subsequent modeling, we were able to offer guidelines on proper placement of detectors and proper alarm settings.

TECHNICAL APPROACH

The program is being carried out by Fire & Risk Alliance (FRA) to obtain experimental data on the time history of dispersion of natural gas inside three different residential layouts/structures and use that data to simulate additional layouts with a good degree of confidence using state-of-the-art computational fluid dynamics. The first task focused on modeling simulations to design the test setup and identify the best locations to place the gas sensors that measured methane concentrations throughout the structures. Later, experimental data from testing was used to optimize the computational fluid dynamics models that simulate gas dispersion. Then, several simulations were run to further enhance our understanding of gas dispersion in residential structures. In the second task, FRA built a two-story structure that simulates a small residence.

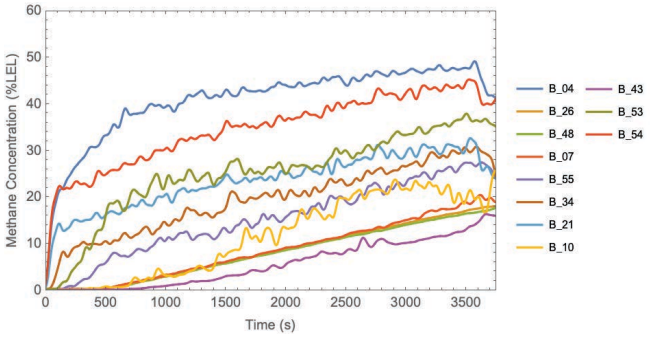


Figure 2: Measurement Results for Test Series 1

The three different layouts tested included: a single-story apartment; a two-story apartment with kitchen and living room area in the first floor and bedrooms in the second; and a two-story apartment with an open floor plan in the first floor (simulating a basement) and stairs to the second floor. The structure was instrumented with temperature, methane and relative humidity sensors. Natural gas release points were introduced to simulate gas release from a stove, a water heater, and an infiltrate line from the "basement" floor. In the third task, the sensor responses were tested at various gas release flow rates, locations, and infiltration rates. While a testing matrix has been developed, the test matrix was finalized with input from the funders. The concentration of methane was measured as a function of time at more than 50 points in the structure to develop a comprehensive temporal/spatial map under varying conditions. The time that it took for the concentration of methane to reach the 10% LEL and 25% LEL thresholds at those sensor locations was recorded and analyzed. (See Fig. 2)

PROGRAM STATUS

The primary recommendations for additional testing at the end of Phase I were to include the installation of a functioning HVAC system to determine detection delays associated with air flows within the enclosure. Phase I testing was replicated in Phase II with mechanical and natural ventilation. Same source types, leak rates and floor layouts were used. Vents were installed on the ceiling, walls, and floor to simulate different systems of air flow seen in typical residence.

A big takeaway from this study was that the presence of an HVAC system (vents and ducts) provides additional pathways and volume for the gas to fill and reduces the gas concentration observed when compared to a space without HVAC. Hence, even when an HVAC system is not in operation, alarm activations may be delayed and at the 25% LEL threshold, activation was often not observed.

Both the studies have been shared with NFPA and the research foundation to aid the creation of the NFPA 715: Standard for the Installation of Fuel Gases Detection and Warning Equipment. Also, work is being done to revise the UL 1484 standard for residential gas detectors.

For more information contact:
admin@NYSEARCH.org

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. Additional testing is underway to quantify the impacts of odor masking agents and Hydrogen blending (up to 20%).**

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 multi-phase 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 desensitization 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) 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%) are underway.

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.

For more information contact:
admin@NYSEARCH.org

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 are being tested in 2021.**

BENEFITS

The benefit of improved effectiveness in a "first pass leak detection" approach is an overall thoroughness of detecting leaks and the 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: Combining RMLD and OPLS walking and wearable technologies with leak location identification superimposed on a street map and gas pipe map

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 (using multiple instruments) is currently underway. This evaluation provides a departure from the typical "H" pattern walking survey, see Figure 3.

Figure 3: Leak survey crews testing and optimizing methods of FPLD advantages using multiple technology instruments

PROGRAM STATUS

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

Field testing is being planned to apply the FPLD approach in actual leak surveys conducted at gas companies. The targeted outcome of this development will be to transform the perform walking surveys into a process with the highest probable rate of leak detection and provide the immediacy of leak classification with appropriate response and records.

For more information contact:
admin@NYSEARCH.org

Highlights

- Walking survey advancements will take advantage of multiple detection technology simultaneously to approach 100% leak detection.
- The project using a statistically-based DOE that collects data from multiple sites supports the use, optimization and standardization of the FPLD process for benchmarking.
- The project aims to increase leak detection capabilities by walking survey will also provide immediate classification of the leak grade.

Reducing Greenhouse Gas Emissions

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 taken from a wide range of flow rates**

Status: **A second phase is ongoing to expand on the findings in Phase I where testing focused on single grid measurements of leaks. Additional testing and expansion of test scenarios and leak dispersion areas are being performed.**

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 on 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%

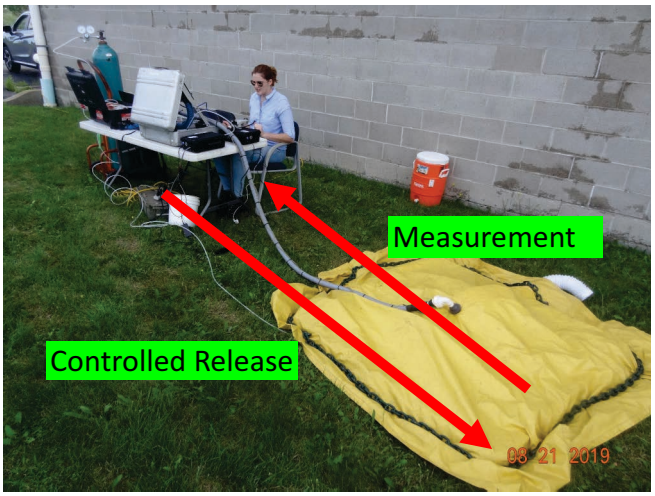


Figure 1: Scene from lab/controlled testing


Figure 2: Scene from initial field testing in New York State 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 2021, a Phase II project was designed to further field test and optimize the measurement process adding the plan to address unique widely dispersed leaks that could cover multiple grid measurements using this process.

PROGRAM STATUS

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

Test planning for live field testing in Phase II are near complete. Sites in upstate and downstate New York are being considered along with other sites in Southern California.


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

For more information contact:
admin@NYSEARCH.org

Highlights

- Surface Expression Measurement is a widely used, stationary benchmarking tool for quantifying methane emissions.
- A statistically-based DOE that collects data from multiple sites supports the use, optimization and standardization of this stationary measurement process for benchmarking.
- Industry and environmental measurement experts can use data from this project to aid collective discussions on the sources of and the uncertainties associated with LDC leaks that contribute to GHG emissions.

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: **Two projects in the program are active and data gathering is ongoing.**

BENEFITS

A formal, scientific testing program to evaluate currently used threaded fittings for 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 and quantify improvements that a stricter thread specification may provide. Such results are intended to aid in making decisions to achieve reductions in greenhouse gas emissions.

BACKGROUND

A focal point for the gas industry and its regulators for many years is and has been safety. 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 reported to account for up to 50% of those distribution system emissions.

The California Public Utility Commission (CPUC) has legislated in SB1371 the need for actions by the California utilities to address various Best Practices as published by CPUC in January 2017.

Best Practice (BP) 22 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, discussed with some manufacturers of gas industry appurtenances, 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 torqueing process.) However, no studies have been done to date to prove this theory.

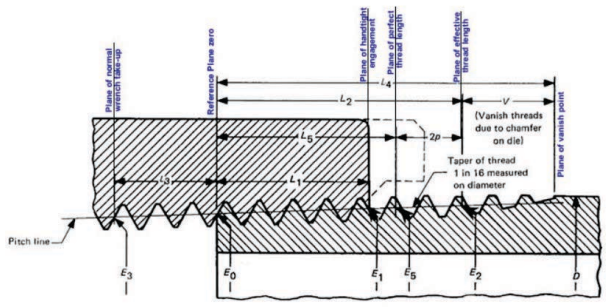


Figure 1: National Pipe Taper Threads

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. Thus, the NYSEARCH members have discussed a broad, multi-faceted program to truly understand the problem.

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. Additionally, the project completed preliminary comparative testing of the performance of joints constructed from fittings meeting the NPT thread specification against joints constructed from ANPT thread specifications, which is a more stringent thread standard. A major finding from this project 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 from Phase II to more severe environmental conditions and an increased cycle count to induce failures. An extended data set, including realistic failure rates, of the behavior of the fittings over time would allow a statistical analysis to provide stronger conclusions. It would also provide 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.

A separate project in this program addresses the need for data regarding the impacts of alternate fuels on the distribution system that aid in decarbonization. Specifically, the impact of blended hydrogen (up to 20%) is being evaluated to test if any changes are expected in the number of leaks from fittings constructed from joints that meet the NPT thread standard. This test effort builds on the earlier phases of this program by subjecting fittings in the test protocol to 20% blended hydrogen and quantify the change in the number of leaks as well as the leak rate, if any develop.

PROGRAM STATUS

Phase III of the project is currently underway, with the procurement, measurement, and selection of fittings appropriate for the task completed. This task supports both the revised test plan as well as the blended hydrogen (up to 20%) impacts study.

Highlights

- A program to measure and evaluate the impact of thread specifications (NPT and ANPT) on the failure and leak rates of threaded connections in Meter Set Assemblies.
- An additional project to evaluate the impact of blended Hydrogen (up to 20%) on failure and leak rates at threaded connections.

For more information contact:
admin@NYSEARCH.org

Northeast GAS ASSOCIATION
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Technology Brief

Methane Oxidation Catalysts for Reduction of Emissions in Flaring

Description: **To develop a catalyst material that can oxidize methane and hydrocarbons at low temperatures and employ these materials in devices to provide a viable alternative to flaring of natural gas.**

Status: **Laboratory prototype development of a thermal oxidizer utilizing the champion Pd catalyst system is underway.**

BENEFITS

Flaring of natural gas is a common practice in industry when necessary to de-pressurize systems and complete blow-downs for maintenance and operations. The result of flaring is the burning or combustion of methane and other natural gas components. A problem associated with flaring is the resultant pollutants that come from combustion of methane particularly SO_x and NO_x.

A new catalyst technology to increase the rate of the combustion process, while lowering combustion temperature would eliminate the release of these pollutants. A catalytic oxidation is also flameless, eliminating the perceived fire risk of flaring operations. The catalytic material could potentially be scaled into a field-deployable product that processes methane at lower temperatures without production of pollutants and a flame.

Figure 1. Methane oxidation reaction: methane mixed with oxygen combusts yielding carbon dioxide and water

BACKGROUND

Current natural gas transmission and distribution operations activities to reduce methane emissions include flaring, drawdown compressors or pump-down techniques, isolation of short sections, and other stoppel techniques. In many situations and depending on state regulations, the economics of drawdown compression limit those activities and then flaring of natural gas is still required. The natural gas industry is exploring new technologies to minimize flaring and other contributors to release of emissions.

NYSEARCH is working with Stanford University to alter the combustion process by using catalysts to reduce the oxidation temperature and thus eliminating the production of NO_x/SO_x. In catalytic methane combustion, natural gas is reacted with oxygen or air mixtures over a solid catalyst at lower temperatures than those at which NOx and other pollutants are formed without the production of a flame. This catalytic approach requires basic research in the laboratory and if successful, could potentially be scaled into a field-deployable process. NYSEARCH and Stanford are determining if a typical volume of gas could be processed through this new form of methane oxidation without pollutants. The practicality of this approach is being investigated but prior work by Stanford on combustion catalysts for different applications shows that the science offers potential.

TECHNICAL APPROACH

The research work focuses on prior work completed by Stanford and with catalysts like the pure metal, Palladium (Pd). Current state-of-the-art

catalysis of methane oxidation occurs with Pd/Al_2O_3, which is palladium particles distributed on an aluminum oxide support. Given a range of volumes of methane to be processed, the amount of Pd catalyst and processing time needs to be optimized. Palladium, like other metals, is expensive and needs to be minimized. Optimization requires effort in investigating the rate of catalyst reaction at various temperatures, exploring different types of supports to distribute Pd particles, and evaluating doping effects on the Pd particles with different types of metals. Evaluating each of these parameters can determine the most optimal Pd catalyst combination to process volumes of methane at low temperatures using minimal amounts of Pd. Laboratory testing is conducted at molecular levels in the nanoscale range. Palladium catalyst modifications and various parameters are synthesized in the lab for testing.

The ultimate goal is to find the best Pd catalyst conditions to: 1) improve the catalytic rate of the current state-of-the-art Pd/Al_2O_3 2) to achieve a process where oxidation of the natural gas would be performed with reasonable amounts of Palladium, and, 3) Achieve these goals in a matter of hours. Once optimization is achieved in a bench scale setup, a first prototype to prove the concept of the new process would be developed.

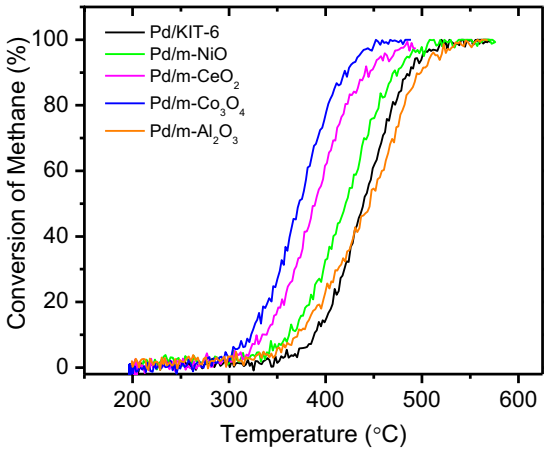

Figure 2. Effect of different metal oxide supports on Pd catalytic rate

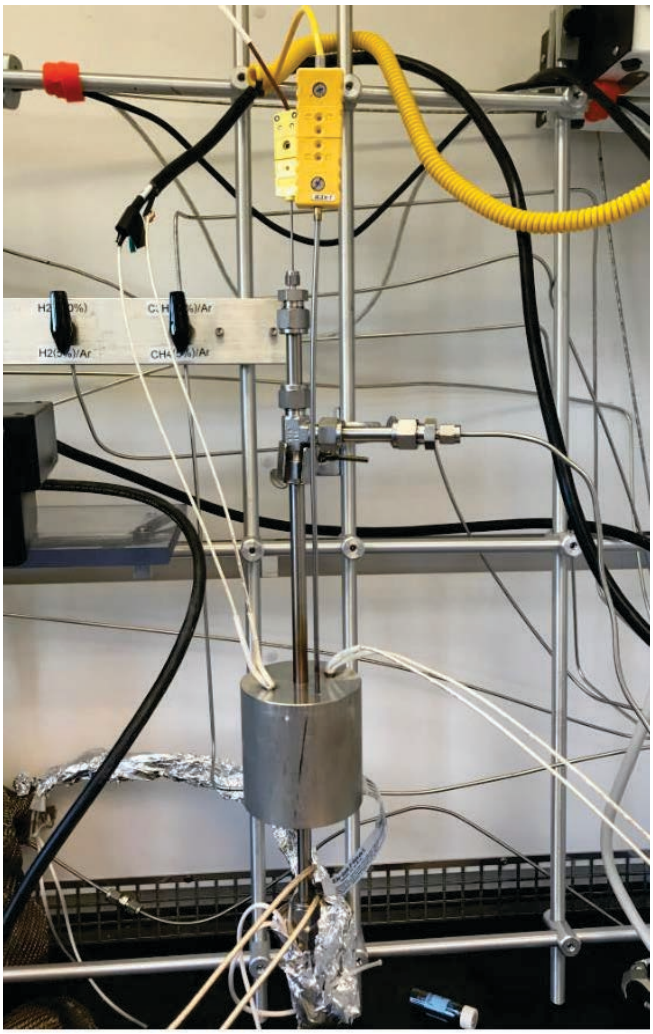

Figure 3. Oxidizer prototype for catalysis testing

PROGRAM STATUS

NYSEARCH is optimizing the current-state-of-the-art Pd catalysis reaction and has identified a champion Pd catalyst system to be used in development of a thermal oxidizer prototype. Further testing in natural gas and development of the prototype is ongoing.

Highlights

- **Palladium catalysis offers an alternative route for methane combustion at lower temperatures with less emissions**
- **Chemical and structural enhancements of Pd particles can increase catalytic rate of methane oxidation**
- **A champion Pd catalyst system is being integrated into the prototype**

Real Time Sensing & Inspection for Distribution

Northeast GAS ASSOCIATION
NYSEARCH

Technology Brief

Small Unmanned Aerial Systems (sUAS) Applied to Traditional Inspections and Surveys

Description: **Perform traditional gas pipeline inspections and surveys by incorporating the agility and positioning of sUAS mounted sensors**

Status: **Advanced development is ongoing with activities that include advancement of sUAS platforms for real time data collection and conditional assessment**

BENEFITS

Advantages of using sUAS agility and positioning are recognized when integrating them into traditional gas inspections and survey strategies. Advantages within leak detection, emergency response, right-of-way management, infrastructure assessment, corrosion severity and distribution/transmission integrity management programs (DIMP/TIMP) have been tested and confirmed.

BACKGROUND

sUAS platforms continue to develop as well as the emergence of smaller, lighter weight and higher sensitivity sensors that are now available for practical pairing with these agile sUAS for consideration of routine and emergency inspections and surveys. Recognizing the value of the technique for the sUAS inspection and survey accessibility, it became evident to NYSEARCH fund that going beyond photographs would further enhance the sUAS capabilities by applying advanced sensors for various applications. All sUAS techniques are designed and performed within the FAA commercial sUAS regulations of Part 107.

TECHNICAL APPROACH

LEAK DETECTION

sUAs mounted sensors are positioned close to an inaccessible pipeline or other asset. A combination of remote methane leak detection and open path bloom detection combine for effective and rapid leak survey confirmation, refer to Figure 1.

Figure 1: Performing leak detection with a sUAS mounted methane sensors

Enhancements to sUAS' leak detection techniques promise advancement in localizing the leak emission point on the ground, refer to Figure 2.

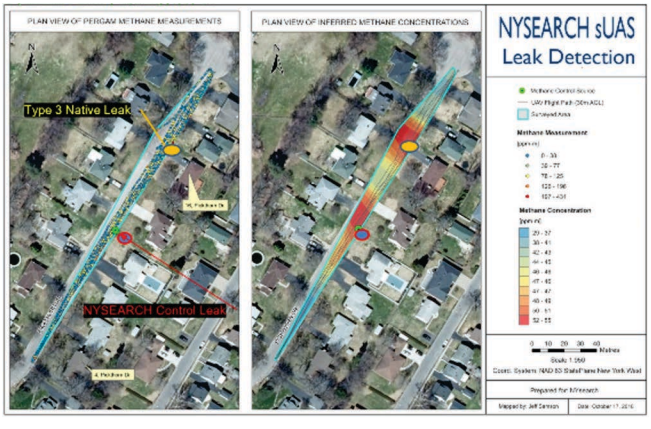

Figure 2: sUAS methane detection survey, red star indicating leak location.

EMERGENCY RESPONSE

Emergency hazards often prohibit personnel and

vehicles with limited or no access to perform inspections and surveys. sUAS techniques have been tested to replace "eyes" and "ears" with sensors to recognize, detect and pattern. Cameras and various sensors can be used to evaluate emerging and changing emergency conditions.

RIGHT-OF-WAY MANAGEMENT

During annual or conditional assessment for right-of-way management, sUAS techniques perform inspections much faster over great distances and over difficult to assess terrain. Incorporation of cameras, LiDar and patterning techniques enable annual reviews to recognize encroachment or damage and anticipate damage before it happens.

INFRASTRUCTURE ASSESSMENT

sUAS mounted with cameras and sensors provide the ability to perform up-close inspection on otherwise inaccessible pipe and pipe structures. Inspection of inaccessible pipeline was successfully completed by positioning the sUAS over 1,000 feet away next to the pipeline while an inspector viewed a monitor, refer to Figure 3.

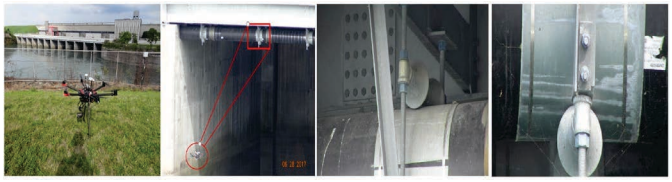

Figure 3: sUAS techniques perform pipeline inspection inaccessible to traditional technique

CORROSION SEVERITY

Difficult to detect and determine severity corrosion damage is readily performed with sUAS techniques. Advancements for measuring wall thickness are being considered, refer to Figure 4.

Figure 4: sUAS corrosion detection location results, GPS specific identification, pipe bridge 750 feet above a navigable waterway

DIMP/TIMP

Multiple combinations of these advanced sUAS inspections and surveys provide more tangible in-depth information for making decisions within Distribution Integrity Management Programs (DIMP) and Transmission Integrity Management Programs (TIMP).

PROGRAM STATUS

NYSEARCH has developed, tested and brought to commercialization various sUAS inspection and survey techniques. Some gas companies have created internal groups to perform sUAS customization while other gas companies have contracted sUAS services.

NYSEARCH has multiple ongoing programs to improve sUAS technologies for localization of leaks, quantification of emissions, detection of leaks emitted from submerged pipelines, as well as corrosion detection and severity assessment.

Highlights

Applying sUAS based inspections and surveys provides:

- **Access where inaccessible pipelines are located**
- **Advanced sensor capability for intended inspections**
- **Records for comparative repeated data collection**

For more information contact:
admin@NYSEARCH.org

Northeast GAS ASSOCIATION NYSEARCH

Technology Brief

Development of Mercaptans Sensor with Non-Radioactive Ionizer

Description: **A program to develop a small, portable, sensor with a non-radioactive ionizer to detect and measure mercaptan concentrations at very low levels using gas chromatography (GC) and differential mobility spectroscopy (DMS) technologies.**

Status: **All sensor components: the non-radioactive ionizer, sorbent trap, power control module, the DMS module, GC, and microcontrollers are currently undergoing integration into a single operating unit.**

BENEFITS

The use of odorants for natural gas detection is considered one of many major public health and safety advancements for the gas distribution industry. Small volumes of certain sulfur compounds known as mercaptans are injected into odorless natural gas to make it detectable. Currently, the primary method to detect mercaptans in natural gas is through operator "sniff" tests and costly gas chromatography lab analyses. A new technology to allow the measurement and detection of mercaptan concentrations at the parts per billion level which is the same level as that detectable to the human nose, would allow a more informed view and reduce the need for utility personnel to sniff natural gas for mercaptans. A highly sensitive mercaptan sensor would also provide rapid, reliable, and continuous results during spot checks throughout the gas distribution system.

BACKGROUND

The odorization of natural gas is a federal requirement and local distribution companies (LDCs) follow their own comprehensive odorization program. Distributed natural gas must be readily detectable with a normal sense of smell at a concentration of one-fifth of the lower explosive limit. To verify this requirement, utility operators perform sniff tests to confirm the gas contains enough odorant. Quantifying the specific concentration of odorant within natural gas distribution lines is one of the main objectives of this project. Precise and detectable rapid quantification of mercaptan concentrations in natural gas are desired.

Following an initial feasibility study evaluating the performance of a non-radioactive mercaptans sensor, detection levels of mercaptan ranging from 0.1 parts per billion (ppb) to 8ppb were established. The human nose can detect mercaptans at concentrations as low as single parts per billion. The successful completion of the feasibility study, laboratory testing, and initial field testing of this project provided confidence in moving forward with further optimization and field testing. However, instability issues around mercaptans chemical degradation were encountered during field testing. UC Davis was identified as the chemical sensor experts to study and resolve these instability issues.

The team at U.C. Davis tested numerous trap materials and identified a sorbent trap that prevented further degradation of the parent mercaptan compound during analysis. The re-configured prototype with this new sorbent trap could detect mercaptans in the single parts per billion range without any stability issues as previously encountered.

The need to develop a portable mercaptans sensor with a non-radioactive ionizer using this new sorbent trap and more advanced separation technologies became apparent as the original components of the mercaptans sensor for the previous NYSEARCH work were no longer

commercially available.

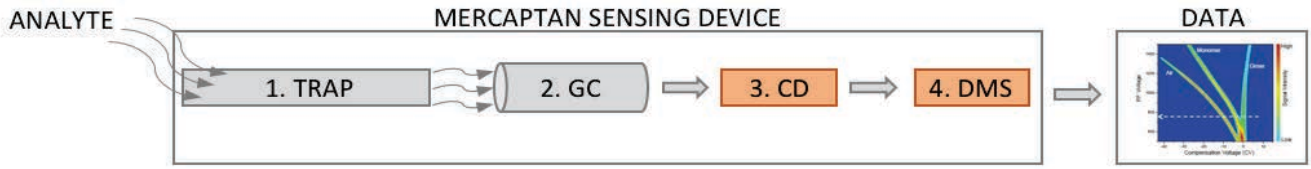

Figure 1. Diagram of mercaptan detection

TECHNICAL APPROACH

The technology of the mercaptans sensor is based on a combination of gas chromatography (GC) and differential mass spectroscopy (DMS). NYSEARCH has tested GC-DMS mercaptans sensors with both radioactive and non-radioactive ionizers. The development of a highly sensitive mercaptans sensor with a non-radioactive ionizer begins with building and optimizing various modules and integrating all those components into a portable field unit. Figure 1 above shows the sample flow of a mercaptan sample.

UC Davis has successfully demonstrated corona discharge (CD) as an adequate non-radioactive ionization source and is in the process of developing and refining the µDMS module to be integrated with the corona discharge system. UC Davis has exhibited substantial knowledge and experience in development and evaluation of Ion Mobility systems of which GC/DMS is a subset. They have worked to modularize newer, more compact systems and through prior NYSEARCH work have solved the instability problem on the original NYSEARCH/ANI system. They have also developed a thorough knowledge of how the system is customized for gas industry in-line mercaptan sensing and smart nose applications.

Five different mercaptans predominantly used in the gas industry are selected for characterization with the newly developed GC/DMS: normal-propyl mercaptan (NPM), tert-butyl mercaptan (TBM), iso-propyl mercaptan (IPM), dimethyl sulfide (DMS), ethyl mercaptan (EM), and tetrahydrothiophene (THT).

Following modular testing with the select mercaptans and integration of all the component modules of the GC/DMS sensor, the prototype will be configured into a portable package as shown in Figure 2.

Figure 2. Model of finished mercaptans sensor with non-radioactive ionizer

PROGRAM STATUS

Benchtop prototype testing is completed. In addition, integration of all the modules were completed prior to organizing a field test. Following successful completion of (2) field tests at a member company in early 2021, the decision was made to proceed to advanced development for optimized field units. Those beta prototypes are intended for optimization and field testing by up to (5) – (10) funding members. The advanced development phase that was started in spring 2021 is cofunded by DOT/PHMSA. NYSEARCH intends on transferring the product to a commercial partner for final product development and introduction to market.

For more information contact:
admin@NYSEARCH.org

Northeast GAS ASSOCIATION

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Technology Brief

GasComm® Analytic Safety Monitoring System for PE Pipe Distribution Networks

Description: **The purpose of this project is to design and build a low cost, battery powered and wireless remote monitoring system to measure multiple real time parameters in previously unmonitored areas of the PE natural gas distribution network. This data, including alarm events, is made available to existing utility RTU's via a GasComm® Control Module or transmitted via secure cellular telemetry to the cloud server of choice.**

Status: **Following specification development, design and development tasks are in progress.**

BENEFITS

The commercialized Enetics GasComm® unit for steel pipes is confirming the ability of this technology to monitor live pipelines in real time. Plastic pipe is the most prominent material used for distribution pipe applications, therefore adapting GasComm® technology for plastic pipe is beneficial to the utilities. With a successful operation of the GasComm® unit for both steel and plastic pipes, the product would expand live gas pipe monitoring technology. The GasComm® unit for PE would also include the Class 1/Division 1/Zone 0 Intrinsic Safety certifications and adhere to ASME pressure boundary requirements.

BACKGROUND

In 2018, eight funders installed (14) GasComm® Beta level systems into a variety of locations in steel pipe distribution systems for a one-year trial period. The single instrument GasComm® node was tapped into live networks, sampling and recording flow, pressure, temperature, water content, and vibration data within these networks. Data was wirelessly transmitted using cellular telemetry to a secure webserver for monitoring, alarm status, and overall performance analysis.

During this Beta field testing program, there were several lessons learned on the physical steps of installation and challenges found with the electronic hardware and software during the installation. The progress gained and experience shared by Member utility personnel during the Beta testing phase proved invaluable to the development team at Enetics. All lessons learned are being implemented in the expansion of GasComm® technology to include plastic pipe operation.

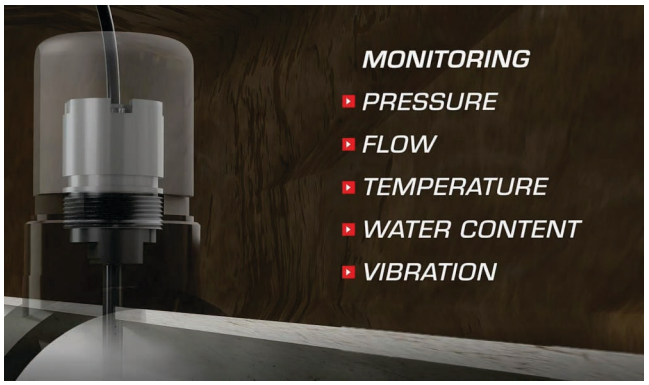

Figure 1: GasComm® Instrument Node

Although GasComm® was developed primarily as an affordable method of monitoring multi-variable status at remote, non-instrumented sites, members also showed interest in allowing existing utility-owned Remote Terminal Units (RTU's) to obtain the GasComm® data.

The ability to use GasComm®'s multi-attribute measurement capability at existing SCADA sites is beneficial to the utilities. Most SCADA sites are already equipped with RTU's, and the ability for GasComm® to directly interface to these RTU's is highly desirable. A dedicated GasComm® Control Module (GCM) is currently in development. The

GCM, powered externally at the SCADA site, can be polled asynchronously by existing utility RTU's using RS485 Modbus protocol, thus making GasComm® pressure, flow, temperature, water content and vibration data available to the utility SCADA system using pre-existing utility security protocols.

TECHNICAL APPROACH

NYSEARCH is designing, developing, and testing products and methods for real-time sensing and alarming in the gas distribution pipeline system for both steel and plastic pipes. Acquiring and analyzing data from various field points in live pipeline conditions are important means to proactively address safety, maintenance, and operational status issues. Additional data enables NYSEARCH members to increase system stability and operational safety methodically and proactively.

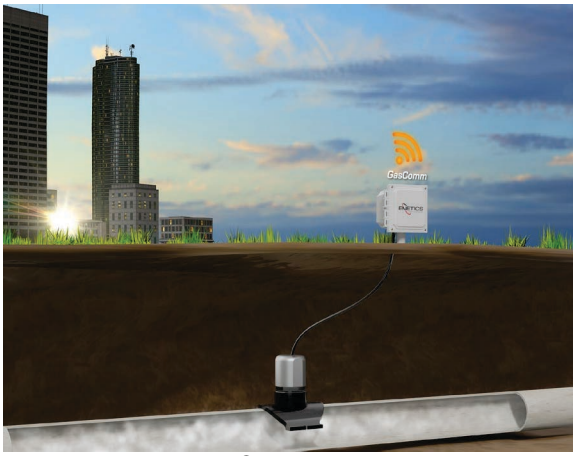

Figure 2: GasComm® Remote Buried Installation

GasComm® is designed to be strategically installed at remote points throughout the distribution system where power is not available and control functions are not required. The data acquired from these points can be used for alarming, asset condition assessment, trending, modeling, improved manpower deployment, and reporting.

The GasComm® instrument is placed into a live, pressurized steel or plastic gas pipe with common hot tap methods and toolsets. In the case of PE piping, a saddle joint is placed onto the plastic pipe and secured using the electrofusion joint process prior to the hot tapping exercise. Either method requires no gas shutoff or customer interruptions and is preferred for existing gas network monitoring.

The GCM will provide control and sequencing for the GasComm® sensor node in addition to Modbus RTU protocol polling communication for existing utility RTUs. This option provides utilities a simple way to incorporate GasComm® data into their existing SCADA data flow without extensive software modifications or hardware updates.

The GCM is housed in a rugged NEMA6/IP67 enclosure and can be installed in the site cabinet, buried, pole mounted, or, for the Class1 Division1 version, installation directly in the hazardous zone. Enetics will offer the necessary intrinsic safety barriers necessary for compliance.

PROGRAM STATUS

The hardware design and tooling requirements for the PE version of GasComm® have been updated and 3D prototypes have been printed. Lab and pressure testing for the 3D prototype are being conducted. Completion of the Intrinsic Safety certification process for the PE pipe design is in progress and expected to be completed in the near term.

The GCM is under development. Field test planning is underway.

Highlights

- GasComm® technology is being extended to include PE pipeline operation.
- GasComm® Control Module (GCM) development is underway to allow GasComm® communication with existing utility RTU's

For more information contact:
admin@NYSEARCH.org

Northeast GAS ASSOCIATION

NYSEARCH

Technology Brief

Energy Harvesting in Gas Industry Applications

Description: **A project to identify, evaluate, and implement devices that utilize energy available within the natural gas pipeline environment to convert it to power.**

Status: **A feasibility study that investigates using a piezoelectric energy harvesting system is nearing field test stage. Field trials for thermal and gas flow energy harvesting devices are ongoing.**

BENEFITS

The deployment of field technologies is frequently limited by the availability of a power supply or the excessive need to maintain a power supply. This is especially true when power lines need to be drawn to remote areas or batteries are needed to be installed to power a certain system. The use of locally available energy through energy harvesting is a solution that is becoming increasingly viable given recent technology developments especially with the advancement of microelectromechanical systems, materials, and rechargeable batteries.

A successful feasibility study would result in the development of engineering systems that could provide a major increase in the capabilities of real time sensing systems like GasComm® Sensor Array (multi sensor system) or smart meters.

BACKGROUND

The gas industry deploys several technologies in the field that require a continuous power supply, for instance, SCADA systems and the GasComm® Sensor Array. Such systems are currently powered by line power, solar panels, or batteries. While these means of powering may be the most efficient in some cases, in other situations the availability of a local power supply is highly desirable. Notably, in cases where batteries are used, the need to replace them over certain intervals of time make some applications not economical and not practical.

Therefore, NYSEARCH initiated a feasibility study to determine whether using energy available in a system's environment to convert it to power has potential for use in the gas industry.

Figure 1: GasComm® Sensor Array

The study examined a wide range of energy harvesting technologies and evaluated their potential for use in the gas infrastructure system from a technical, economic, and technology maturity perspective. In the feasibility study phase, there were four (4) energy harvesting devices that proved to have potential deploying into the natural gas system. In the current phase, we are carrying out an analysis and/or design of each one of the technologies.

TECHNICAL APPROACH

The benefits and imitations of known energy harvesting technologies were examined through an exhaustive search of existing literature and investigation of best-in-class electronic devices across a variety of energy harvesting technologies. The four (4) types of energy harvesting devices that were researched and/or being tested are: fuel cell energy, gas flow energy, thermal energy, and vibration energy.

The first technology evaluated was the fuel cell energy harvesters. Solid oxide fuel cells utilize the pipeline gas as a fuel source. Fuel cell harvesters are commercially available with propane and natural gas solid oxide fuel cell systems to provide the power to the units of interest. However, research discovered that fuel cell energy was very expensive and the cost of maintenance to clean the fuel in the fuel cell was very high.

The second technology researched was gas flow energy. Gas flow technology uses a miniaturized turbine to convert the energy in the flow of pipelines to rotational energy and then, using an electric generator, convert to electricity. The Parker Zeus differential pressure battery charger showed promising results when tested in the lab to power the GasComm® Sensor Array.

Figure 2: Energy Harvester – Parker Zeus

Another technology that was investigated is thermal energy. It utilizes the difference in temperature between the natural gas flowing in a pipeline and the surrounding soil to harvest energy using a thermoelectric system. The Gentherm thermoelectric generator also showed promising results when testing in the laboratory.

Figure 3: Energy Harvester – Gentherm

A fourth technology that was evaluated utilizes vibration energy through piezoelectricity. Piezoelectricity is the electric change that accumulates in certain solid materials such as crystals or certain ceramics. The device will harvest the natural vibration energy of pipelines with the use of the ceramic material.

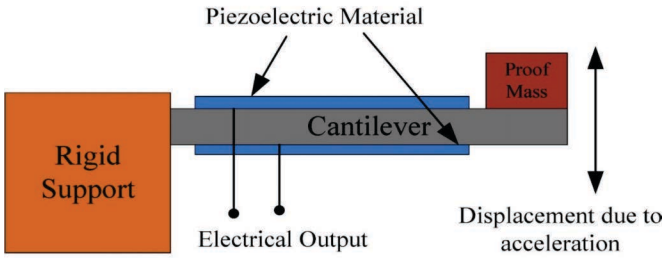

Figure 2: Piezoelectric Design Concept

PROGRAM STATUS

The gas flow energy and thermal energy technologies have been tested and analyzed in the lab. These devices are ready for field testing to improve upon the understanding of the devices and to test the energy harvesting abilities with the GasComm® Sensor Array.

The piezoelectric energy feasibility effort is expected to document the target power requirements for the GasComm® Sensor Array. At the conclusion of the study, the results of a shaker test and the characteristics of the mounting system to build a piezoelectric system are being documented in a report.

Highlights

Energy harvesting for this application:

- Eliminates the need to replace batteries over certain intervals
- Provides a solution to powering remote systems.

For more information contact:
admin@NYSEARCH.org

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Appliance Test Setup