Southern California Gas

San Diego Gas & Electric

SUMMARY REPORT FOR SENATE BILL (SB) 1371 RESEARCH AND DEVELOPMENT PROJECTS AND PILOT STUDIES SUPPORTING THE UTILITIES 2018 LEAK ABATEMENT COMPLIANCE PLANS

March 31, 2020

Prepared by:
Southern California Gas Company

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Executive Summary

SoCalGas and SDG&E has compiled this written evaluation of the results and/or status of the SB-1371 Research & Development projects conducted in support of the 2018 Compliance Plan and is intended to be shared with the California Public Utilities Commission (CPUC)'s Safety and Enforcement Division (SED), other utilities, and other interested parties for the purpose of advancing knowledge and information for the reduction of fugitive and vented emissions from the Natural Gas Transmission, Storage, and Distribution system.

1. Introduction

In support of SB 1371 SoCalGas has executed multiple research projects. This report includes a short write-up on each of the projects. Section 2 contains projects that are complete (14). Section 3 contains projects that are active (22).

2. Completed Projects

The following 14 projects are complete. Research projects contain milestones which are useful to determine whether a project should continue. Of the 14 completed projects listed below, 2 were cancelled for technical reasons and 2 are progressing to a next phase.

2.1. Natural Gas Pipeline Integrity Safety and Integrity Management (CEC GFO-15-506) Group 2 BP 16 X-1

Lead Sponsor: California Energy Commission (CEC)
Status: Completed

1. Objectives:

   This project resulted from a solicitation by the California Energy Commission under GFO-15-506. The project was awarded to DNV-GL and UCLA researchers and resulted in a Final Project Report titled *Demonstration of a Multi-Analytic Risk Management Tool for the California Pipeline Industry, August 2018, CEC-500-2018-023*. The project goals and objective were to:

   - Customize the existing Bayesian Network models for corrosion and mechanical threats to the California natural gas pipeline system.
   - Demonstrate the advanced risk assessment method by applying it to a natural gas pipeline system with a major Californian pipeline company.
   - Transfer the knowledge gained by openly publishing and presenting the project's results and lesson learned to the industry, government and public sector.

2. Background/Approach

   Natural gas pipelines are subject to a complex combination of threats that can also interact and affect system integrity. These threats can cause unanticipated pipeline failures that pose a safety hazard to the public and cause economic hardship. Pipelines are also subject to natural forces such as seismicity and soil movement, and are located in different terrains with varying topography, ground cover, and climates. They are often hidden from sight in populated areas along with other types of underground utility assets that can encroach on the gas pipelines and interfere with their protective systems. The complex mix and interaction of variables in the pipeline system and operating environment can be evaluated using advanced mathematical and probabilistic approaches to improve threat predictions and cost benefit analysis.

3. Accomplishments

   DNV GL developed and demonstrated a software-based threat model MARV™. The threat model or method has the ability to make threat predictions on a gas pipeline using industry data and can identify sections of pipeline that are most at risk. The Bayesian method is used in the MARV™ software and can update the probabilities based on new information when available. The MARV™ probability estimation process can be started when only small

amounts of data are available. The statistical sensitivity of the probability estimation to causative threat factors can also be used to prioritize the collection of additional data. Since the MARV™ method can be updated with new data, integrated with sensors to perform real-time risk assessments may also be possible. The MARV™ method also predicts and shows the results in a probabilistic distribution format with clear uncertainty (that is, it generates all possible outcomes with corresponding probability). This is different from conventional modeling approaches that use deterministic values to provide narrowly defined results and ignore other possible outcomes.

DNV GL identified indicators that could be monitored to mitigate external corrosion, and they also identified third party-damage probabilities. They also created a method that identifies the most useful data using a cost-benefit analysis approach.
The Final Report was issued and socialized with the industry contacts. However, the software application is not yet commercially available.

4. Conclusions

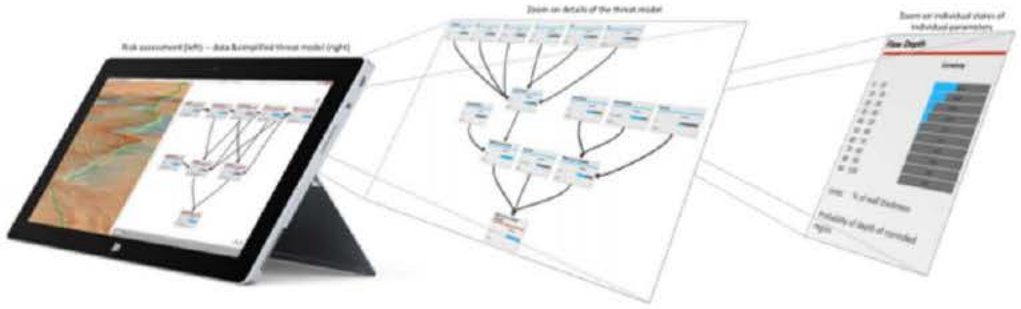
SoCalGas believes the MARV™-based decision-making approach can help pipeline operators determine what data is most useful and help answer questions such as "What data would reduce uncertainty of threats the most?", "What data should we gather first?" and "When do we have enough data?". The knowledge gained from being involved and the information provided in the final report is currently used by Pipeline Integrity and to enhance risk management methods.

5. Next Steps

SoCalGas has had a number of discussions about obtaining the tool and using the software. While a commercial product is not yet available, one is being developed. At this time, the model is provided as a service and is not being sold as a commercial software tool. However, there is interest by the recipient team in incorporating this in a suite of software tools and eventually selling it commercially.

6. Citations/References –

1. F. Ayello, N. Sridhar, A. Mosleh, C. Jackson, Demonstration of a Multi-Analytic Risk Management Tool for the California Pipeline Industry, August 2018, CEC-500-2018-023, Agreement Number PIR-15-506.



Source: DNV GL

2.2. Fast Accurate Leak Detection (PRCI ROW-3H) BP 17 Z-1

Sponsor: Pipeline Research Council International
Status: Completed

1. Objectives:

   The objective of this two-phased project was to develop a portable handheld instrument capable of pin-pointing leaks in natural gas distribution systems and then configure and integrate the instrument into a small Unmanned Aerial System. The sensor technology is based on Jet Propulsions Laboratory's open path laser spectroscopy originally developed for NASA's Mars Land Rovers for measuring the presence of methane on the planet.

2. Background/Approach

   The Jet Propulsion Laboratory (JPL) has developed a highly sensitive methane and ethane sensor called the Open Path Laser Spectrometer (OPLS) which detects methane to 10 parts-per-billion (ppb) and ethane to 1 part-per-billion (ppb) and weighs several hundred grams. Because of its sensitivity, OPLS can identify methane point sources tens to hundreds of meters away.

   This laser-based technology is lightweight and has superior sensitivity to methane, the primary component of natural gas. The device would guide an operator's crew using a tablet interface to possible leak locations, fast-tracking their ability to find leaks.
   Due to its fast response, OPLS can resolve meter to sub-meter plume features. The combination of these characteristics presents new ways to find and quantify the flux of methane sources.

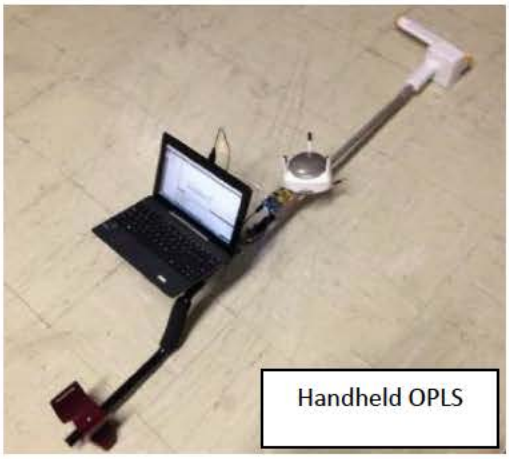
3. Accomplishments

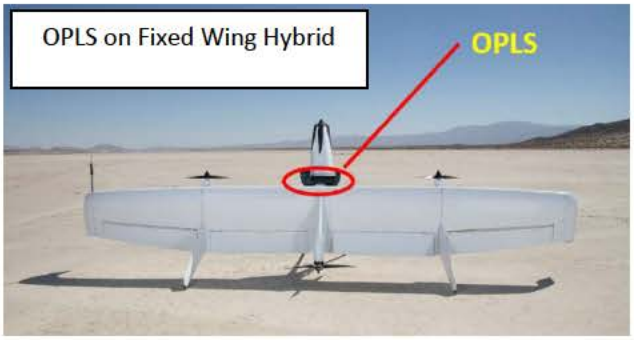
   JPL successfully developed a new OPLS laser that can measure both methane and ethane.

   JPL partnered with PG&E and SoCalGas to test their prototype handheld OPLS gas leak detection tool at their respective training centers (PG&E's Livermore Training Center and SoCalGas's Pico Rivera Situation City).

   JPL and UC Merced tested a small unmanned aircraft system (sUAS) equipped with the OPLS over an oil and gas production site.

   JPL worked with Swift Engineering to integrate the OPLS on a fixed-wing hybrid sUAS with vertical take-off and landing capabilities and flew it over a Southern California dry lake bed.





4. Conclusions

Successful development efforts have resulted in licensing the OPLS technology to three vendors; RKI Instruments, Union City, CA, SeekOps, Austin, TX, and Dynetics, Huntsville, AL. Ruggedization of the instrument for both ground and sUAS implementation has matured to the point that it is now commercially available.

5. Citations/References –

1. PR-459-133750-R03 Fast, Accurate, Automated System to Find and Quantify Natural Gas Leaks
https://www.prci.org/Research/SurveillanceOperationsMonitoring/SOMProjects/ROW-3H/6080/172025.aspx

2.3. Evaluation of Methane Detection Devices for Utility Operations (OTD 7.17.e) BP 17 AC-1

Sponsor: Operations Technology Development
Status: Complete (Progressing to Next Phase)

1. Objectives(s):

   The stated objective for this project was to:

   "Evaluate new and advanced methane detection devices[1] for potential use in the following applications: walking leak survey, leak investigation and stationary remote monitoring."
   The stated business value for this project was:

   "The adoption of these new advanced methane detection technologies can improve the ability to identify and locate leaks resulting in a more efficient leak detection and repair process. These technologies also have the potential for remote monitoring of target assets that may require frequent longer-term detection of methane."

2. Background/Approach

   Four technologies were selected for evaluation from a candidate list of technologies:

   - [redacted] designed as a personal wearable device monitor for worker safety. GTI was interested in evaluating the performance of this unit as a potential stationary remote monitor. Detection limit in the % LEL range (not ppmv range).
   - [redacted] designed as a personal wearable device monitor for worker safety. GTI was interested in evaluating the performance of this unit as a potential stationary remote monitor. Detection limit in the % LEL range (not ppmv range).
   - [redacted] mid-IR laser-based system that measures methane and ethane and may have applicability for leak investigations/walking leak surveys.
   - [redacted] - cavity-based laser system that can measure methane, but does not measure ethane, and may have applicability for leak investigations/walking leak surveys.
   - [redacted] – methane sensor with spot ethane measurements that may have applicability for leak investigations/walking leak surveys.

   Testing included two tasks:

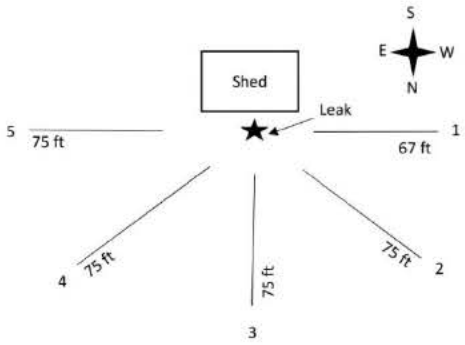
[1] i.e., "devices that can detect methane at concentrations at the parts per billion level (ppb), far below typical background atmospheric methane concentrations, which is approximately 2 parts per million (ppm)."

- Validation of Technical Specifications (Lab Testing). A test matrix to validate the technical specifications of the [redacted] methane detection analyzers was implemented. Technical specifications include "detection level, sensitivity, accuracy, precision, false positives, repeatability and reproducibility of results."
- Field Evaluation. Target applications were "a walking leak survey, leak investigation and stationary remote monitoring." A test site/simulated leaks was used for the walking survey

3. Accomplishments

A. limited work scope was conducted. Proposed validations of technical specifications for sensitivity, accuracy, precision, false positives, repeatability, and reproducibility were not conducted. Detection levels were determined for methane in nitrogen.

Walking path evaluations of the [redacted] and [redacted] analyzers, shown schematically in the figure to the right, were conducted. The table below shows results from the [redacted] test with a large leak rate (~56 scfh). Green high-lighted data indicate methane and/or ethane concentrations greater than background. A walking path evaluation of the [redacted] analyzer was not conducted due to weather conditions.



	Spoke 1		Spoke 2		Spoke 3		Spoke 4		Spoke 5	
Start Time:	2:30 PM		2:41 PM		2:49 PM		2:55 PM		3:03 PM	
Distance (ft)	CH_4 (ppm)	C_2H_6 (ppb)	CH_4 (ppm)	C_2H_6 (ppb)	CH_4 (ppm)	C_2H_6 (ppb)	CH_4 (ppm)	C_2H_6 (ppb)	CH_4 (ppm)	C_2H_6 (ppb)
75			2.10	9.20	2.13	0.50	2.04	3.20	2.50	18.20
71			2.06	10.00	2.13	0.50	2.04	3.20	2.10	18.30
67	2.10	(1.00)	2.06	10.00	2.13	2.30	2.03	1.70	2.10	18.30
63	2.10	(1.00)	2.06	11.20	2.13	3.20	2.60	39.00	2.70	24.20
59	2.10	2.30	2.04	12.60	2.11	1.50	2.70	15.00	2.01	19.50
54	2.10	6.00	2.03	13.10	2.10	6.10	2.70	23.90	2.01	19.50
50	2.10	9.30	2.03	15.00	2.09	9.20	2.07	0.90	2.01	21.30
45	2.10	10.40	2.03	15.00	2.06	11.30	2.20	(3.20)	2.10	21.70
40	2.10	11.40	2.03	15.00	2.06	13.60	2.20	(2.60)	2.10	20.30
35	2.08	11.60	2.03	16.20	2.06	14.70	4.20	51.30	2.10	21.40
31	2.08	11.60	2.04	16.00	2.05	17.60	2.09	(8.50)	2.10	21.40
28	2.08	12.40	2.05	15.70	2.05	19.10	2.10	(8.50)	2.01	19.80
25	2.07	12.10	2.06	14.10	2.05	19.10	2.07	(7.90)	2.13	21.60
21	2.07	12.60	2.07	13.20	2.05	21.10	2.06	(7.50)	3.80	72.20
18	2.06	12.90	2.07	13.20	2.05	20.30	2.06	(7.00)	16.70	750.00
15	2.05	13.60	2.08	11.20	2.06	20.30	2.05	(5.80)	2.08	18.90
12	2.04	14.70	2.10	6.80	2.06	19.20	2.05	(4.10)	2.10	19.60
9	2.05	15.30	2.07	(1.40)	2.06	18.20	2.16	(1.90)	3.70	91.00
6	6.50	210.00	2.40	24.00	2.06	17.30	2.16	(1.90)	100.00	760,000.00
3	13.80	150,000.00	2.60	21.00	34.00	1,500.00	2.04	1.30	2.56	37.80
0 ft	1,200.00	300,000.00	6,000.00	200,000.00	800.00	320,000.00	196,000.00	15,000,000.00	6,000.00	1,000,000.00
End Time:	2:40 PM		2:48 PM		2:55 PM		3:03 PM		3:09 PM	

4. Results

The [redacted] was evaluated as an ambient monitor; however, it is designed as an [redacted] monitor. Very large methane concentrations would be needed for the [redacted] to detect natural gas emissions. In addition, the monitor has limited battery power; thus, the [redacted] is generally not suitable for use as an ambient monitor for the applications targeted by this study.

The evaluations of the walking path instruments [redacted] analyzers, had technical deficiencies. GTI did not evaluate the instruments for the use-case of detecting typical Distribution system leaks. Examples of these technical deficiencies include:

- Response time tests were conducted with 100 ppmv methane gas rather than low concentrations (e.g., < 10 ppmv) that would better evaluate the potential added value of high-sensitivity analyzers.
- The study walking path evaluations of the [redacted] analyzers were conducted with leaks ranging from 7 to 56 scfh and thus did not evaluate performance for detecting small leaks (i.e., 2 scfh and less) that are the majority of distribution network natural gas leaks.

5. Conclusions

The [redacted] is generally not suitable for use as an ambient monitor. The field evaluation text matrix was very limited and did not include the leak rates typically found for the use case of Distribution system leaks. Further work would be needed to determine the utility of the [redacted] instruments, which will be performed under other projects related to individual devices selected for further study.

6. Citations/References

1. "Operations Technology Development NFP. (2018). Research Project Summaries" https://www.otd-co.org/newsroom/Documents/OTD-Research-Project-Summaries-2018.pdf

2.4. MEMS Sensor Development Project (Stanford NGI) BP 18 AE-1

Sponsor: Stanford University Natural Gas Initiative (NGI)
Status: Complete (Cancelled)

1. Objectives:

   This was a collaborative research and development project through Stanford University intended to produce a working prototype of a microelectrochemical gas sensor (MEMS) targeting use by Natural Gas Utilities. This Stanford MEMS project intends to develop and demonstrate the capability of a microfabricated electrochemical sensor to detect and identify methane in air at a concentration of 1% or below. Successful development efforts may result in an advanced low-cost sensor that can be used as an option for methane detection and monitoring applications where traditional methane sensors may not be feasible, such as Meter Set Assemblies.

   The expected outcome of this project was for Stanford University to provide SoCalGas with a beta version of the sensor for controlled laboratory testing at SoCalGas.

2. Background/Approach

   Previous work on MEMS sensors by the Stanford project team was published in 2017 and 2018 (see references). Successful sensors for continuous leak detection are expected to be:

   - Sensitive and Selective to Natural Gas molecules, especially Methane
   - Able to differentiate the detected molecules to avoid false positives
   - Inexpensive and easy to manufacture
   - Miniaturizable and low power to be mass deployed

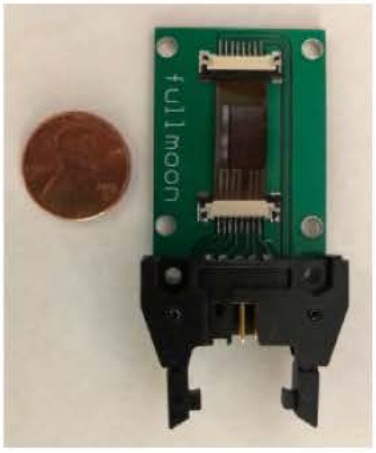
   The intended approach for this project includes the development and testing of prototype sensors by Stanford Researchers followed by the delivery of a beta-version sensor for testing at SoCalGas.

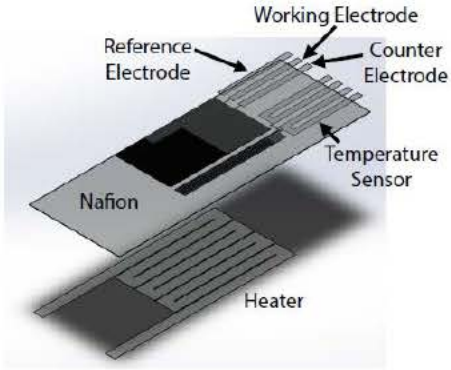
   SoCalGas was to independently test and evaluate beta-versions of the sensor in a Controlled Laboratory Test for sensor sensitivity (minimum detection level), accuracy and repeatability. In addition, power requirements and sensor data communications would be assessed. Results of sensor testing would be compared to stated capabilities as received from Stanford Researchers.

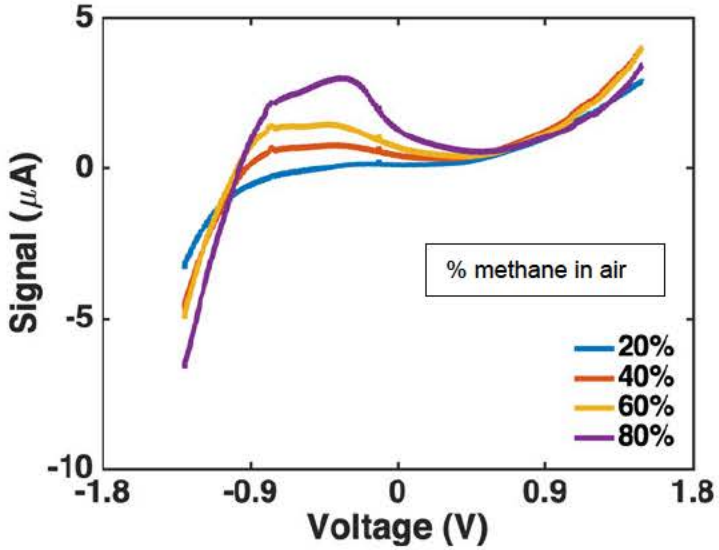
3. Accomplishments

This project was based upon a multi-layer silicon-based sensor approximately 1 cm x 1.5 cm in size that was developed, and results published in 2018. Improvements to this original sensor were necessary to fulfill field deployment requirements. The following changes and results were reported:

- Replace silicon base with Nafion (polymer electrolyte) to address hydration and enable higher throughput manufacturing method
- Doping of the Nafion has enabled "dry" operation with improvements in sensor baseline and voltage range.
- Methane in air has been detected in the micro-ampere range at 20 – 80% methane in air.







Sensor Response to Methane in Air (2019)

Further improvements in the performance of the system were expected with the inclusion of temperature control in the sensor, sensor redesign to increase sensitivity and to enable ethane and methane differentiation, and feedback from the results of prototype testing by sponsors.

During this project, the researchers formed a start-up company, Full Moon Sensors. Neither Stanford University nor Full Moon Sensors provided SoCalGas with any protype sensors at any level of development during the course of this program.

The presentation by Full Moon Sensors at NYSEARCH in 2019 did not progress beyond proof-of-concept. Full Moon presented insufficient information to support claims.

4. Conclusions

The resources that are required to support this program would be better spent on other technologies at this time. Further funding and support of this project has been discontinued at this time. If and when Full Moon is able to demonstrate sufficient progress in development of a viable sensor with test data to support their technical claims, then continuation of the project will be reconsidered.

5. Citations/References –

1. PA Gross, T Jaramillo and B Pruitt, Cyclic-Voltammetry-Based Solid-State Gas Sensor for Methane and other VOC Anal. Chem. 2018, 90, 10, 6102-6108
2. PA Gross, E Sadeghipour, T Jaramillo, and B Pruitt, Presentation to PG&E and SoCalGas June 15, 2017 “Gas Sensor for Continuous Natural Gas Leaks Detection”
3. PA Gross, E Sadeghipour, T. Kenny, and T. Jarmillo at Stanford NGI Industrial Affiliates Meeting, October 9, 2019 “Gas Sensors for Continuous Monitoring”

2.5. State of Art Methane Sensors (OTD 7.16.f) BP 18 AE-2

Sponsor: Operations Technology Development
Status: Complete (Cancelled)

1. Objectives(s):

   The stated objective for this project was to:

   "Investigate the current state of the art in "point" methane sensors and how they are used in the utility industry. A gap analysis will be performed and sensors (such as from [redacted] may be selected for further investigation and testing based on the gaps identified."

2. Background/Approach

   The stated business value for this project was:

   "The value will be derived by correlating the current (and possible future) uses for methane sensing in the utility industry with the various technology solutions and their associated costs. This will provide a roadmap to determine if there are applications where new or disruptive sensing technologies can provide greater value than current practices."

   The project was conducted in two primary tasks. The first task investigated the current state of and uses for methane measurements - these include investigations that utilities conduct that require methane measurement (e.g., use cases such as leak surveys, leak investigations, leak monitoring) and associated regulatory requirements; makes and models of equipment currently in use; and industry experience with the equipment. The second task included the collection and documentation of the current state-of-the-art for methane sensors and how they are applied for industry use cases; a technology gaps analysis (e.g., gaps or marginal fits between existing sensors and use cases); and recommendations for potential future testing of sensor technologies to fill current knowledge gaps in sensor technologies.

3. Accomplishments

   A report was written detailing the results of the tasks described in Section 2. An optional third task, evaluation of [redacted] sensor technology, was not conducted because the [redacted] sensor was not yet ready for evaluation.

4. Results

   The investigation of industry use cases determined that current applications of methane sensor technologies typically fall into three main categories: leak surveys, leak investigation,

and leak monitoring. Applicable regulatory requirements that were identified included Federal regulations (e.g., 49 CFR 192, Subpart W of 40 CFR 98) and numerous state regulations that are more stringent than the Federal 192.173 regulation that pertains to distribution system leakage surveys[2]. Companies use a wide variety of equipment from multiple manufacturers for methane detection and quantification including flame ionization detectors, catalytic combustion sensors, thermal conductivity sensors, infrared sensors (closed and open path), infrared imaging cameras, advanced laser spectroscopy sensors, and Light Detection and Ranging systems.

Descriptions of current sensor technologies for methane measurement were provided, with the technologies generally categorized by cost and detection limit. For each technology, information including technology description, applications, cost, and subjective lists of advantages and disadvantages were provided. Descriptions of sensor technologies in the developmental stage were also discussed, with technology descriptions and developmental status provided. Tables summarizing key information for all these technologies were included in the report.

Project sponsors identified instrument cost (hardware, software, and O&M) and sensitivity as the main drivers of methane sensor technology implementation. Technologies that result in more efficient and cost-effective leak surveys are a goal for new sensor development. For example, low cost disposable technologies, passive technologies, technologies that increase the area that a crew can cover and accurately identify leaks (e.g., unmanned aerial vehicles (UAVs) surveys), and technologies that can quantify as well as detect gas leaks.

Recommendations for addressing technology gaps included:

- Development of a clearly defined set of needs and use cases for new methane measurement technologies being developed.
- Testing the [redacted] technology when development is completed.
- Evaluations of the emerging ARPA-E MONITOR technologies.

5. Conclusions

This report provides a high-level reference for methane sensor technologies. Additional, more detailed, investigation would be required before selecting a technology(s) for purchase and implementation.

[2] Arkansas, California, Connecticut, Delaware, District of Columbia, Florida, Illinois, Indiana, Kansas, Kentucky, Maine, Maryland, Michigan, Minnesota, Missouri, New Hampshire, New Jersey, New Mexico, Ohio, Pennsylvania, South Carolina, Tennessee, Texas, Virginia, Washington, and Wisconsin.

6. Citations/References

1. "Operations Technology Development NFP. (2018). Research Project Summaries" https://www.otd-co.org/newsroom/Documents/OTD-Research-Project-Summaries-2018.pdf

2.6. Field Measurement of Leak Flow Rate - Phase 2 (OTD 1.14.d.2) BP 20a AI-1B

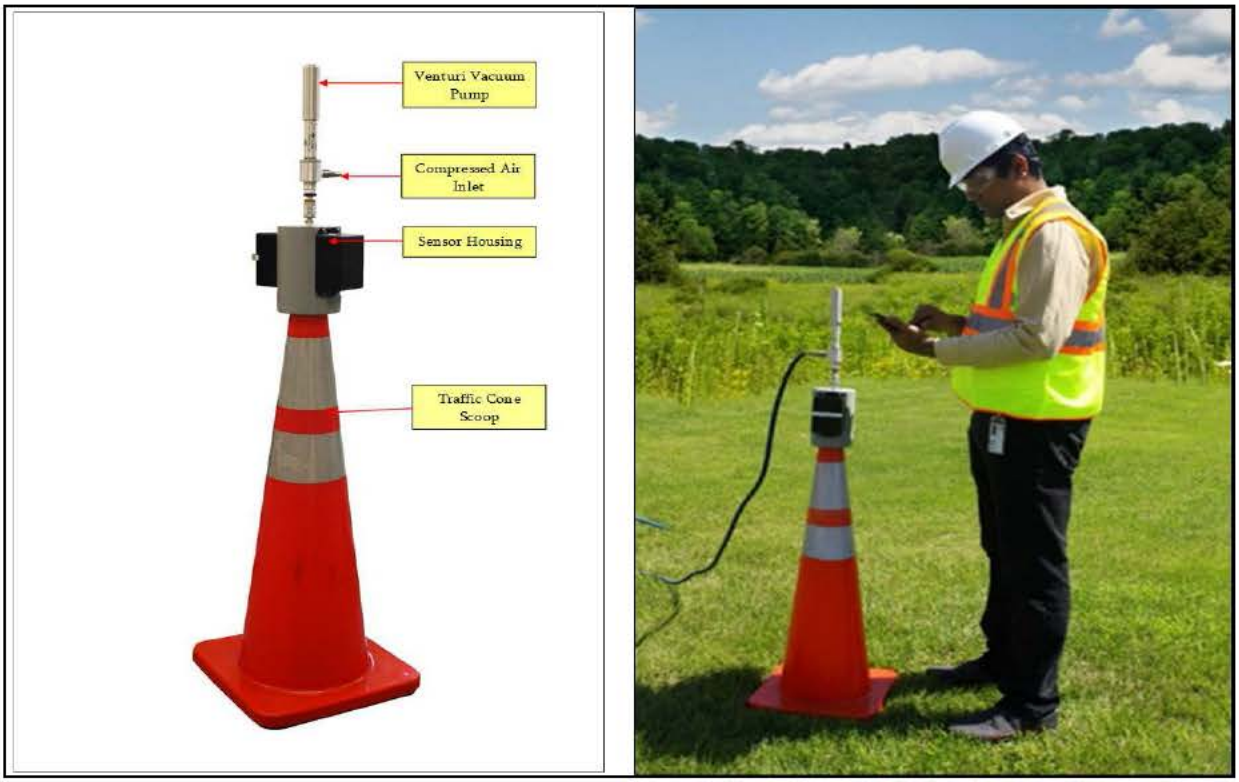
Sponsor: Operations Technology Development
Status: Complete

1. Objectives(s):

   The overall project objective was to develop an inexpensive and repeatable device that could provide a quick and easy measurement of the natural gas emission rates on distribution network leaks.

2. Background/Approach

   This project evaluated a Methane Leak Rate Tool (MLRT) prototype. The MLRT components are a thermal mass flowmeter, a NDIR methane sensor, and a venturi vacuum pump. For the prototype, the components are mounted atop a traffic cone and the cone is placed over an underground gas pipeline leak (see the Figure below). The vacuum pump pulls air and leaking gas (i.e., sample gas) through the flowmeter (which measures scfm of sample gas) and methane sensor (measures volume % CH_4 in sample gas), and the gas leak is the product of these two measurements.



3. Accomplishments

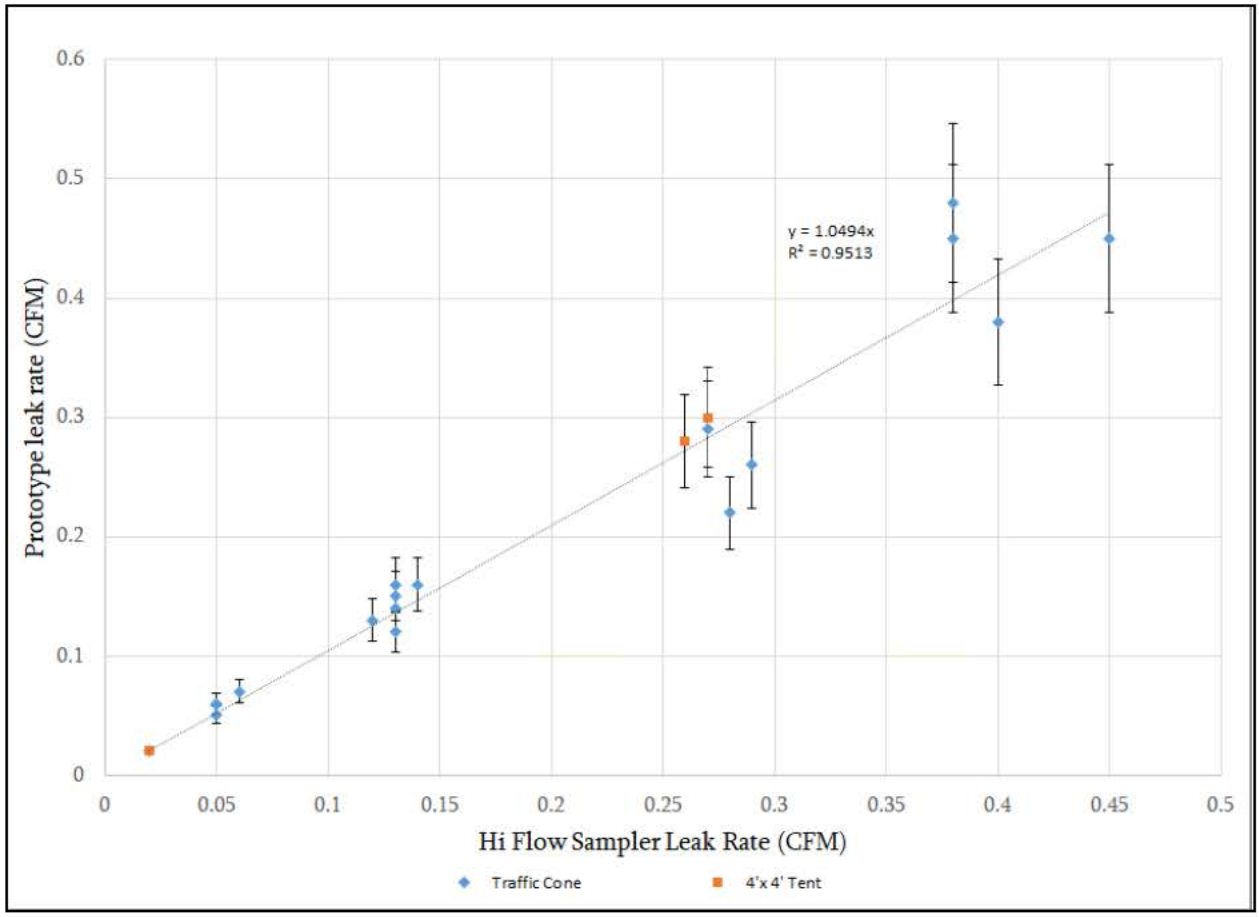
The MLRT components (methane sensor and sample gas flowmeter) were individually evaluated and then MLRT leak rate measurements were compared to Hi-Flow Sampler® measurements for a point source (i.e., metered methane from a tube).

4. Results

The individual testing of methane sensor and the sample gas flowmeter showed:

- the measured methane concentrations were generally within 10% of the calibration gas concentrations and thus consistent with the manufacturer specified accuracy of + 10%; and
- air flow sensor measurements were within 2% of the flowrate measured by a calibrated flow meter, which was within the 3.5% reading accuracy of the flow sensor.

For the point source testing, the MLRT leak rates were within 5.5% of those quantified using the Hi-Flow Sampler® as show in the figure below.



5. Conclusions

Based on the point source testing, the MLRT shows promise for the measurement of leaks that express from a very small area (i.e., the footprint of the MLRT protype is a traffic cone with a footprint area of less than one square foot). However, leaking gas from underground pipelines often expresses over a large area and the efficient capture of large area leaks often requires multiple tarp (4' x 4' enclosure) locations or a very large enclosure. Coupling the MLRT with such enclosures should be a consideration for any further research to determine its applicability for large leaks (e.g., determine how its performance compares to a Hi-Flow Sampler® or other flowmeter/methane sensor system).

6. Citations/References

1. "Operations Technology Development NFP. (2018). Research Project Summaries" https://www.otd-co.org/newsroom/Documents/OTD-Research-Project-Summaries-2018.pdf

2.7. Methane Emissions Studies – Residential Customer Meters (CARB) BP 20a AI 4.2 & 4.4

Sponsor: CARB (SoCalGas / SDG&E)
Status: Completed

1. Objectives:

   This was a Research & Development project sponsored by the California Air Resources Board (CARB) and conducted by the Gas Technology Institute (GTI) to study emissions from residential natural gas meter set facilities and to develop emission factors.

2. Background/Approach

   Senate Bill 1371 (SB1371) required the adoption of rules and procedures to minimize natural gas leakage from CPUC-regulated utilities to reduce the greenhouse gas emissions.

   For this project, CARB was interested in developing specific emission factors for residential customer meters. An example of a residential customer meter with threaded piping connections is shown below:

3. Accomplishments

   Data collection was completed for SoCalGas and SDG&E. GTI developed a draft report which is reportedly under review by CARB. [redacted]

4. Conclusions

This project was limited in the scope of work to Residential Meter Sets and limited in regard to the scope of the random sampling. The study does a good job of demonstrating that most [redacted] of SoCalGas and SDG&E facilities have no measurable leakage. The majority of the facilities that do have leaks are very small leaks in regard to flow rate, with the average being [redacted] and the largest being [redacted] Further work and pilot studies will be performed under project BP 20a AI- 4.6 & 4.7 to develop leaker-based emission factors that will better estimate system emissions from all type of meter set facilities.

5. Citations/References

1. *2015 WSU/EST Study – "Direct Measurements Show Decreasing Methane Emissions from Natural Gas Local Distribution Systems in the United States"*, Lamb et al, Environmental Science & Technology, 2015, 49, 5161-5169
2. *California Air Resources Board (CARB)*. 2020; Available from: https://ww2.arb.ca.gov
3. GHD Emission Factor Development for Natural Gas Compressors, PRCI Catalog No. PR-312-16202-R02, April 18, 2018.
4. Methane Emission Factors for Compressors in Natural Gas Transmission and Underground Storage based on Subpart W Measurement Data, PRCI Catalog No. PR-312-18209-E01, October 17, 2019.

2.8. Pipe Thread Sealant Performance (OTD 5.18.w) BP 22

Sponsor: Operations Technology Development
Status: Completed

1. Objectives:

   The objective of this project was to identify high-performing pipe thread sealants that can prevent premature threaded joint gas leaks for typical ranges of pipe size, material types, operating pressures, and environmental conditions. Identification of a high-performing thread sealant would have a positive impact on utility O&M expenses, methane emissions, and employee safety.

2. Background/Approach

   In collaboration with the project sponsors, 17 pipe thread sealant products were identified. These were categorized into three types - regular, PTFE, and anaerobic. The products were subjected to technical and market analyses followed by performance testing. Sealant behavioral trends under experimental field conditions were observed, and best-performing products were recognized.

   Performance testing consisted of fabricating three (3) schedule 40 black steel and three (3) 304 stainless-steel test assemblies with each pipe thread sealant candidate. These test assemblies were exposed to a 10-day temperature cycling protocol (-20 to 140°F) while pressurized up to 450 psig and monitored for leaks. Supplemental high-performance testing was continued for the nine (9) best-performing products. This testing consisted of the following additional tests: (1) high-pressure testing to 1700 psig (2) impact testing which consisted of dropping a test assembly 3 times to achieve an impact energy of 4.9 ft·lbs followed by pressure testing to 450 psig (3) torque removal testing which measured the torque required to disengage each component from a test assembly and (4) viscosity temperature dependence which measured changes to the consistency of the pipe thread sealant due to temperature.

3. Accomplishments

   In general, the anaerobic-type products performed better during the temperature and pressure tests than the regular- and PTFE-types, but the cost of the anaerobic-type products is much greater. A significant number of leaks among the regular- and PTFE-type products were observed during pressurized testing following the temperature cycling protocol. Additionally, more leaks were observed among the 304 stainless-steel assemblies than the schedule 40 black steel. Of the 17 products initially tested, nine (9) best-

performing products were identified for phase 2 performance testing. During phase 2 performance testing, only two (2) leaks were observed throughout high-pressure testing at pressures greater than 1500 psig, and none were observed following impact testing. Torque removal testing determined that many of the anaerobic products were unable to be disengaged. A total of three (3) cost-effective regular- and PTFE-type products with leak prevention results equal to the anaerobic-type products were identified from the testing protocol and recommended for usage. These products were [redacted]

Thread Sealant

Test Specimen

Overall Best-Performing Thread Sealants

Product Name	$/oz	Pressure Limit (psig)	Sealing Temperature Range (°F)	Compatibility	Volatile Organic Compounds (g/L)
[redacted]		2,600	-50 to 400	Black Steel/Stainless-Steel	317
		6,000	-50 to 400	Black Steel/Stainless-Steel	54.4
		2,000	-15 to 300	Black Steel/Stainless-Steel	0
		2,000	-15 to 300	Black Steel/Stainless-Steel	317
		10,000	-65 to 400	Black Steel/Stainless-Steel	59.4
		10,000	-65 to 375	Black Steel/Stainless-Steel	<0.15% by weight
		Pressure rating of pipe	-55 to 230	Black Steel/Stainless-Steel	20
		Pressure rating of pipe	-65 to 400	Black Steel/Stainless-Steel	<0.1% by weight
		10,000	-65 to 350	Stainless Steel	<1% by weight

4. Conclusions

All nine (9) of the best-performing products prevented leaks during high-performance testing with the exception of two leaks observed at pressure loads above 1500 psig. [redacted] were identified as the most as cost-effective pipe thread sealant products. These products demonstrated performance results on par with anaerobic-type products, at lower costs. These products maintained a seal at pressures up to 1700 psig, had good vibrational resistance, and demonstrated minimal temperature influence on viscosity.

5. Citations/References –

1. "Operations Technology Development NFP. (2018). Research Project Summaries" https://www.otd-co.org/newsroom/Documents/OTD-Research-Project-Summaries-2018.pdf

2.9. Develop Methods to Mitigate Gas Blown to Atmosphere Research Project (OTD 5.16.n) BP 23 AO-1

Sponsor: Operations Technology Development
Sub-project Sponsor: SoCalGas / SDG&E
Status: Completed

1. Objectives:

   The project investigated traditional planned blowdown procedures of venting natural gas to the atmosphere and compared them to alternative methods such as flaring and re-capture of the blowdown gas. The analysis included the projected economic, environmental, and social impacts for each method if they were to be implemented in regular service. Recommendations for alternative blowdown methods were prepared.

2. Background/Approach

   Utilities are evaluating best practices to reduce their emissions of methane, a greenhouse gas, beyond current efforts based on safety. For example, some utilities decided to voluntarily participate in EPA's Natural Gas STAR Methane Challenge Program. This voluntary program requires companies to take steps to mitigate emissions of natural gas.

   A change in venting practices could impact the total amount of methane emitted by the United States. Certain situations sometimes require venting natural gas to the atmosphere during pipeline blowdown procedures. This takes place when a section of pipeline needs to be serviced or a newly installed pipeline must be purged of air.

   Avoiding a blowdown has many benefits to both the utility and the environment, but to maximize these benefits, a utility must carefully choose the correct alternative method. There are various solutions and numerous variables which must be considered to determine the optimal technology or practice to utilize.

3. Accomplishments

   OTD report:

   Nine blowdown alternatives were identified and assessed: for Transmission Pipelines (Stopples/Plugging Equipment, Mobile Compressors, Flaring, Portable Thermal Oxidation, Methane Recapture and Transport); for Distribution Pipelines (Gas Recovery Unit, Enclosed Combustion, Zero Emission Re-capture and Vacuum Pump Method).

The report presented a case study of two natural gas utilities (SoCalGas and SDGE) to gain an understanding of the magnitude of typical blowdown operations. This information was presented at the AGA Spring Operations Conference in 2017. The following table compares blowdown average values in the MJ Bradley & Associates report with SoCalGas/SDGE[1].

	MJB&A (intrastate)	SoCalGas/ SDG&E	Unit
Average Pipeline Diameter	15.2	24.5	inches
Average Pipeline Pressure	400	412	psig
Blowdown Length	15	5	mi/event
Blowdown Volume	230	630	Mcf/mile
	3500	3100	Mcf/event
Blowdown Methane Mass	5	13	MT/mile
	72	65	MT/event

Final report was submitted to the Company's Field Technologies group which then initiated field demonstrations of one selected technology, [redacted] Zero Emissions and Compression System.

SoCalGas/SDG&E Demonstrations:

Demonstrations were implemented and the equipment selection was based on the pressure rating, blowdown, and footprint. [redacted] scored well in these areas considering the following:

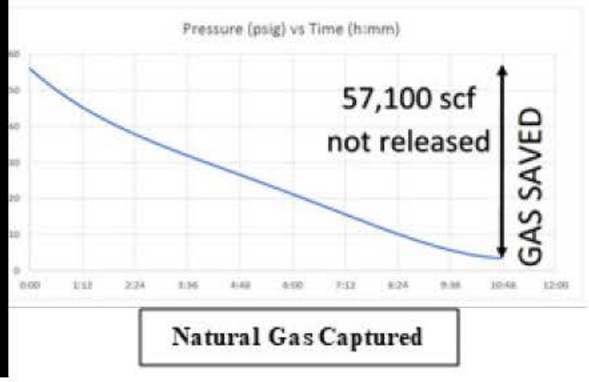
- Pressure rating: There are various [redacted] units that range from a pressure rating of 200 psig up to 1500 psig. This versatility means these units can be used across the company

- Blowdown time: Utilizing several units in series and adjusting the units to match the application (pressure rating) the blowdown time can be decreased from just using one unit alone.

- Footprint: The [redacted] units are fairly compact. One unit and a compressor can fit on the back of a ¾ ton pickup truck. Even pairing several in series can be mounted on back of a trailer and towed.

A demonstration of the equipment took place at SDG&E in March 2019. A natural gas distribution main comprising of 1.6 miles of 10" dia. and 1.6 miles of 16" dia. pipe was drawn down from 57 psig to 3 psig. The gas was transferred to another section of the distribution main.

[redacted]



Following the sucessful demonstrations, 20[redacted] units of various capacities have been purchased and are used in both SoCal and SDGE's service territories.

[redacted]

4. Conclusion

Vented natural gas emission can be reduced by employing various alternatives to venting. A utility that strives to decrease its annual methane emissions should examine the most common operational scenario in which venting gas is a key issue. However, none of the methods described in this report are applicable to all blowdown scenarios.

Type of Gas Delivery	Operating Pressure	Volume of Gas to be Evacuated	Parallel Pipeline Present?	Surrounding Area	Recommended Alternatives to Blowdown
Transmission	High	Low	Yes	N/A	Mobile Compression and re-insertion into parallel pipeline
			No	N/A	Methane Recapture and Transport
				N/A	Stopple system bypass
		High	Yes	N/A	Mobile Compression and re-insertion into parallel pipeline
			No	N/A	Mobile Compression and re-insertion past the shut-off point
				Remote	Flaring
				Developed	Portable thermal oxidation
Distribution	Low	Low	Yes	N/A	Gas Recovery Unit Compression into parallel pipeline
			No	N/A	Gas Recovery Unit Compression into portable vessel
				N/A	ZEVAC System (Compression and storage for transport)
				Remote	Flaring
				Developed	Combustion in Portable Heater

Summary of blowdown alternatives and the scenarios where they are most applicable

5. Citations/References –

1. Haines, Deanna. "Case Study Comparisons Against MJB&A Report "Pipeline Blowdown Emissions &Mitigation Options." Southern California Gas Company and San Diego Gas & Electric. November 10, 2016. Houston, TX.
2. Lowell, Dana, Brian Jones, David Seamonds, and Pye Russel. "Analysis of Pipeline and Hazardous Materials Safety Administration Proposed New Safety Rules: Pipeline Blowdown Emissions and Mitigation Options." M.J. Bradley & Associates LLC. June 2016. Concord, MA.
3. "Operations Technology Development NFP. (2018). Research Project Summaries" https://www.otd-co.org/newsroom/Documents/OTD-Research-Project-Summaries-2018.pdf

2.10. GIS Platform & Data Model for Mobile Data Collection (OTD 8.17.e) BP 20b AM-1

Sponsor: Operations Technology Development
Status: Completed

1. Objectives:

   This was a Basic Research & Development project to develop a modular software system to gather and store field data electronically to minimize data error that can be introduced with multiple manual data entries. It consisted of two major components:

   1. A core mobile GIS platform
   2. An integrity management module supporting the collection of data produced by field activities such as integrity assessments, examinations and evaluation, repairs, prevention and detection[3].

   The objective of this project was to speed up flow of information, automate data QC, improve data integrity, and improve spatial alignment of data. The module for data related to system emissions and leak data would be developed in a later phase.

2. Background/Approach

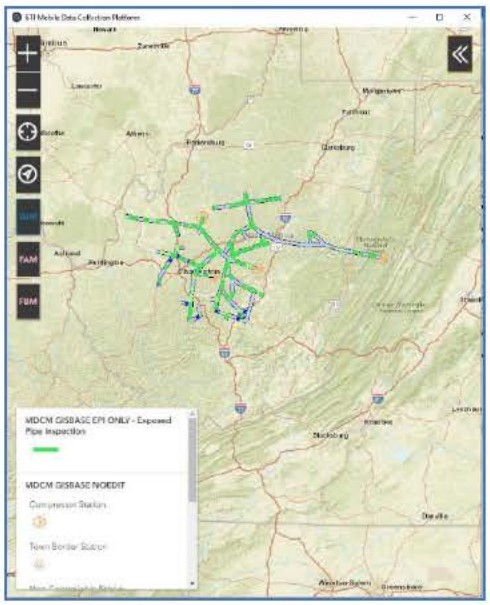
   Accurate, meaningful methane emissions data collected in the field by gas operations personnel will continue to become more and more critical to comply with Federal and State emissions reporting requirements and developing mitigation schedules. This technology is intended to streamline methane emissions related data collection that could impact the development of new Emissions Factor (EF) and emissions inventory reporting. Emission factors associated with fugitive emissions could be improved or affected by the results of this project.

   Phase 1 is to produce a pre-prototype of the integrity management module and the core GIS platform. The module will contain all the business logic necessary to support data collection activities. The core GIS platform is intended to support common field workflows and communication with the module. The phase 1 pre-prototype is intended to focus on field data available during maintenance and repair of pipeline facilities.

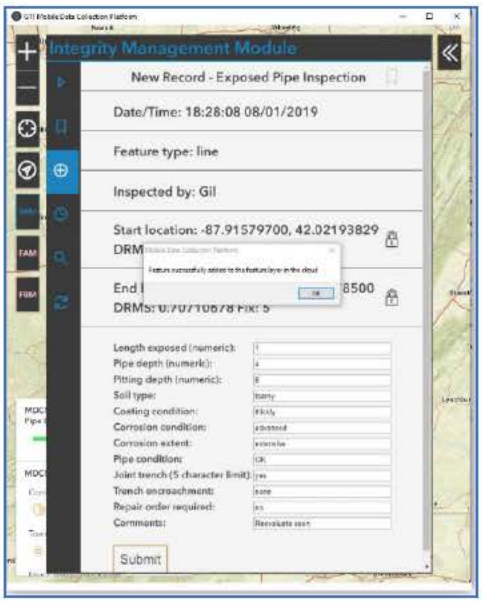
[3] Reference 6.3

3. Accomplishments

Phase 1 of this project was completed in the third quarter of 2019. The documented list of required system functions and architectural or technological requirements is complete. The data model development is complete.



Mobile GIS Platform



Integrity Management Module

Although this first phase produced meaningful progress toward the program end goals, additional work is required to fully realize the value of the solution. The following section describes the planned next steps for technology development. This work will depend on OTD funding member interest.

Phase 2

A follow-on project would further develop the software system. A more detailed requirements and design specification would be developed via a rigorous analysis of ASME B31.8s Managing System Integrity of Gas Pipelines and GTI subject matter expertise. Data collection needs specific to requirements related to in line inspection (ILI), Pressure Testing, external corrosion direct assessment (ECDA), internal corrosion direct assessment (ICDA) and stress corrosion cracking direct assessment (SCCDA) techniques would be incorporated into the application. Based on these detailed requirements, the alpha prototype would be hardened into a beta prototype including detailed application programming interface (API) documentation. The API documentation would be the guide to adding GTI's module to a utility's existing software.

Phase 3

A second follow-on project would be needed to mature the prototype created in Phase 2 into a beta prototype based on lessons learned and sponsor feedback to date. The beta prototype would be further tested and improved via pilot projects and demonstrations. Potential commercialization would be part of this phase.

It is expected that at the conclusion of Phase 3, GTI would have produced a viable, competitive, tested, and commercial-ready product.

4. Conclusions

The work completed in this phase created a prototype of the field data collection software. This progress was critical to prove out some of the software design theories that GTI had developed for creating open data collection modules. The final report was presented and delivered to SoCalGas subject matter experts. Currently, the continuation of the project to Phase 2 has not been approved by members.

5. Citations/References –

1. "Operations Technology Development NFP. (2018). Research Project Summaries" https://www.otd-co.org/newsroom/Documents/OTD-Research-Project-Summaries-2018.pdf

2.11. Validation Study of Advanced Detection and Quantification Technologies for Natural Gas Transmission and Storage facilities (SCG-2017-008) BP 20a AG-1

Sponsor: SoCalGas
Status: Complete

1. Objectives(s):

   Evaluate the ability of selected advanced mobile methane emissions technologies to detect, differentiate, locate, and quantify gas emissions sources within the complex terrains and environments (e.g., variable winds & temperatures) typical of SoCalGas natural gas transmission and storage (T&S) facilities.

2. Background/Approach

   Two mobile technologies that function based on the principles of "remote and indirect" measurements using instruments with parts per billion (ppb) sensitivity and used within relative proximity to emissions sources (no greater than 150 feet) were evaluated:

   - [redacted] – AT1
   - [redacted] – AT2

   A comprehensive double-blind study was conducted that included:

   - Controlled (metered) natural gas releases (emission sources) from three geographically diverse test sites representing the complex operations environments (i.e. diverse terrain, variable wind) typical of SoCalGas T&S facilities
   - AT1 and AT2 conducted surveys to detect, differentiate, localize, and quantify emission sources for a total of 190 Test Conditions (98 for AT1 and 92 for AT2):
     - Individual gas releases ranged from 0.1 to 90 SCFH

  - Maximum Test Condition total release rate of 230 SCFH (from 3 gas releases)
  - Numerous replicate Test Conditions with 1 to 3 emission sources
- Atmospheric conditions varied and were recorded for each Test Condition (winds, temperature, barometric pressure, cloud cover, relative humidity)

AT1 and AT2 results were compared to their Stated Capabilities and to SoCalGas study benchmarks needed for a practical level of performance by the T&S operating organizations.

3. Accomplishments and Results

For the majority of the performance parameters, AT1 and AT2 did not achieve their stated performance capabilities and the study benchmarks:

- Detection of emissions was 96% for all Test Conditions (AT1 and AT2 combined performance)

- Differentiation of emission sources was achieved for only 61% of all emission sources (AT1 and AT2 combined performance vs. Stated Capabilities of 90% and 100%)
  - Actual number of emission sources per Test Condition was not reliably determined
  - AT1 revised capability statement - cannot differentiate emission sources separated by less than 150 feet
  - AT2 revised capability statement - cannot differentiate emission sources separated by less than 40 feet
  - Poor differentiation is a limitation of these technologies because the actual number of leaks can be greater or less than the detected number of leaks. Without conducting a thorough post-investigation (current practice) Operators cannot be confident that they have repaired all leaks, or Operators may spend time searching for leaks that do not exist (when the actual number of leaks is less than the reported number of detections).

- Localization of all release points in accordance with the study benchmark was not achieved
  - AT1: 22%; AT2: 70%

- Poor localization increases the time required by operators to find leaks

- Quantification - AT1 and AT2 were not able to reliably quantify gas releases to stated capabilities
  - AT-1 quantification estimates are within an "order of magnitude" (+200%/-70%) of actual flow rate with 80% confidence when an adequate number of measurements through the plume are obtained; however, estimates for high flow rate emissions were biased low.
  - Increasing the number of measurements (surveys) for a Test Condition improved the quantification estimate (reduced the confidence interval)
  - Poor quantification estimates would cause operators to incorrectly prioritize leaks for repair, resulting in increased vented emissions and incorrect estimations of gas losses.

Based on the test results, 1.) AT1 and AT2 revised their capability statements, generally to a lower performance standard; and 2.) adjusted algorithms to improve performance. These revised capabilities and adjusted algorithms were not evaluated by subsequent independent testing.

4. Next Steps

Project Completed.

5. Conclusions

SoCalGas must conduct LDAR for CARB O&G GHG rule compliance at T&S facilities and could not utilize AT1 or AT2 to conduct LDAR surveys. The technologies provided insufficient leak detection identification, detection differentiation, localization, and quantification to be fit for the LDAR use-case. Significant knowledge was gained in capabilities of advanced technologies and requirements that must be specified to achieve desired results. Leak quantification accuracy and precision were dependent on atmospheric conditions and the ability of the technology providers to obtain multiple plume cross-section measurements. Potential technology advancement and improvement opportunities were identified. There was a side benefit of this project for SoCalGas in improving internal processes for conducting controlled release studies.

While the current state of performance demonstrated by these technologies preclude use for the targeted use-cases, other use-cases may be appropriate depending on the project objective.

6. Citations/References

1. [redacted]

2.12. Distribution System Characterization - Vintage PE Pipe and Industrial Meters (OTD 7.16.h) BP 20a AI-2

Sponsor: Department of Energy (DOE)/performed by Gas Technology Institute (GTI)/ Operations Technology Development
Status: Complete

1. Objectives(s):

   The overall project objective was to investigate large uncertainties associated with the estimate of methane emissions from equipment in natural gas distribution systems. Project foci included improving the characterization of emissions from industrial and commercial customer meters and researching potential differences between vintage and modern plastic pipelines.

2. Background/Approach

   Industrial/Commercial Customer Meters

   The US EPA Greenhouse Gas Inventory (GHGi) uses the definitions of industrial and commercial sectors provided by the Energy Information Administration to identify industrial and commercial meters. The GHGi estimates emissions from industrial and commercial meters using emission factors (EFs) from historical data that may not represent emissions from present day equipment. These EFs have large uncertainties and may be biased; thus, there is a need for more accurate, lower uncertainty EFs. To address this need, an extensive customer meter characterization and leak detection and measurement program was conducted. The data were analyzed to determine EFs as discussed in Section 4.

Industrial and Commercial Meter Sets

Vintage Plastic Pipelines

Based on available records of pipeline production and installation, this study identified plastic (e.g., polyethylene (PE)) pipe installed before 1986 as "vintage" and plastic pipe installed after 1986 as "modern." A recent GTI/OTD report suggests modern plastic pipe has lower emissions than vintage plastic pipe [2]. Vintage plastic pipe has been shown to experience "slow crack growth" (i.e., stable growth of a crack with little pipeline deformation) [3]. Consequently, there is a need to understand the differences between emissions from vintage and modern plastic pipe, and the potential benefits of modern plastic pipes. To address this need, an extensive plastic pipeline leak measurement program was conducted. The data were analyzed for differences in leak rates between vintage and modern plastic pipelines as discussed in Section 4

3. Accomplishments

Industrial/Commercial Customer Meters

Thirteen field sampling campaigns were conducted to document and measure leaks from industrial and commercial meter sets[4] in six U.S. geographical regions (Midwest, Northeast, Pacific, Rocky, Southeast, Southwest). 24,670 components operated by ten different companies were screened for emissions from six types of industrial/commercial meter sets (diaphragm, turbine, rotary, ultrasonic, orifice, and regulating equipment). 1,474 components had a leak concentration greater than 100 ppm and emission rate measurements were conducted for 458 individual components.

Vintage Plastic Pipelines

To evaluate potential differences between methane emissions from underground vintage plastic pipe and modern plastic pipe, ten field campaigns were conducted in five of the six U.S. geographical regions (Midwest, Northeast, Pacific, Rocky, Southwest). Gas leak rate measurements were performed using a Hi Flow® sampler couple with a surface enclosure. 339 potential underground leak sites were screened for gas and gas emission rates were measured at 186 sites. Pipe repair data was obtained from operators in order to confirm the appropriate material category was applied. Of these measured leaks, 58 leaks were from vintage plastic pipe and 45 leaks were from modern plastic pipe (i.e., a total of 103 from plastic pipe).

[4] Meter set refers to the meter and all components (e.g., valves, connectors) associated with the meter before the point of transfer of hardware responsibility to the customer for the natural gas.

4. Results

Industrial/Commercial Customer Meters

Distributions of emission rates for individual components were right-skewed and heavy-tailed. This distribution indicates that a small fraction of leaks contributed a large fraction of the total emission rate. Meters, caps, and regulators were the components with highest average emission rates (i.e., EFs). Table 1 lists the population EFs for industrial and commercial meters, all (nationwide) and by region, determined by this study. For this study the all (nationwide) industrial/ commercial meter EF is 78.9 kg CH4 kg CH4 /meter-yr, or about a factor of 8 times greater than the current GHGi EF of 9.7 kg CH4 /meter-yr. The data also showed:

- There were differences in EFs by region (see Table 1);
- The industrial meter EF is greater than the commercial meter EF (see Table 1).
- The turbine meters EF was greater than the EFs for rotary and diaphragm meters (see Figure 1)

These findings indicate that emission estimates based on meter sub-categories (i.e., region, meter type, and industrial or commercial) would be more accurate than emission estimates based on the nationwide aggregate industrial/commercial meter emission factor. In addition, conducting leak surveys and appropriately applying leaker EFs rather than applying population EFs to all meters would be expected to provide a more accurate emission estimate.

Table 1. Population EFs for Industrial/Commercial Meters by Region (kg CH4/yr)

	Commercial			Industrial		
	Mean	Standard Deviation	Total Sample Size	Mean	Standard Deviation	Total Sample Size
All	57.4	223.6	337	117.8	404.4	186
Midwest	28.4	145.5	99	52.3	183.2	77
Northeast	20	43.7	75	172.5	413	13
Pacific	4	9.5	63	17.4	100.1	52
Rocky	108.4	348.9	12	322.5	609.8	9
Southeast	139.3	292	5	291.7	707.1	15
Southwest	153.9	377.7	83	372.9	799.6	20

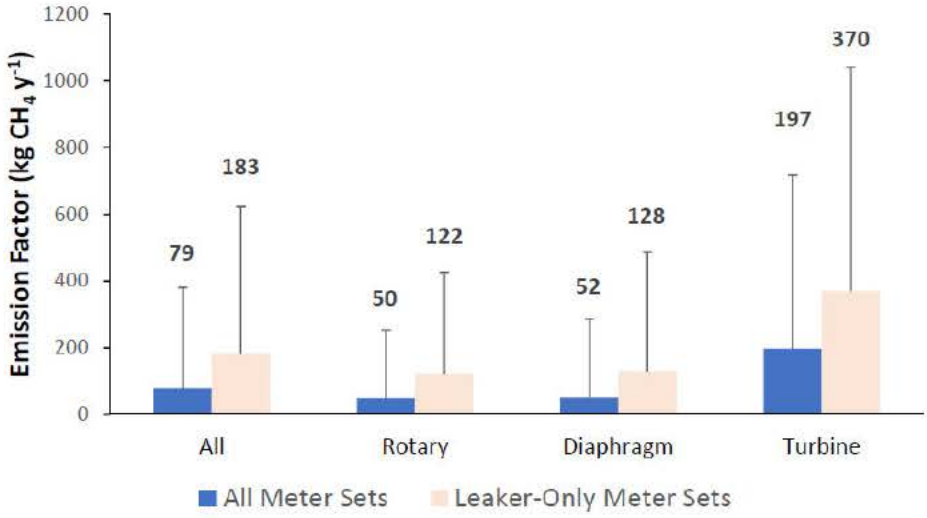


Figure 1. Comparison of Leaker Factors and Population EFs by Meter Set Type

Vintage PE Pipelines

After one methane emission rate measurement outlier for vintage pipe was removed (2,254 g/hr), the average measured emission rates for the vintage and modern plastic pipes were similar. The average methane emission rate for vintage plastic pipe was 48.7 ± 78.4 g/h. The average methane emission rate for modern plastic pipe was 40.9 ± 83.2 g/h. This limited data suggests there is an insignificant difference in the flow rates of individual leaks between vintage and modern plastic pipes. It should be noted that this study had a limited sample size that may not be completely representative of the population of leaks from vintage and modern plastic pipes. The one outlier data point for vintage plastic pipe was removed, but this leak could indicate that very large leaks are more prevalent in vintage plastic pipe. Conversely the small sample size may not have included very large "outlier" leaks from modern plastic pipe.

A finding of the study was that assigning underground leaks to specific pipe material is not reliable without excavation and verification of the pipe material. Numerous leaking pipelines were determined to be materials other than plastic upon verification. Several factors could contribute to mis-classification of a leaking pipeline material (without excavation and verification) including differences between actual leak location and where the leak emissions are expressed on the surface, multiple types of pipe materials in the area (materials used for Mains and Service are often different vintages), and operator records (including materials used in fitting components).

5. Conclusions

This study provides useful information for SoCalGas. The study compiled and analyzed leak emissions data from a large sample of industrial and commercial customer meters. The results indicate that the emission factor currently used by the GHGi to estimate emissions from these meters under-estimates these emissions by about an order of magnitude. The data indicate that more granular meter data and emission factors (e.g., industrial or commercial meter, meter type, geographic region) provide more accurate emission estimates than application of the nationwide aggregate industrial/ commercial meter emission factor. In addition, conducting leak surveys and appropriately applying leaker EFs rather than applying population EFs to all meters would be expected to provide a more accurate emission estimate. Limited data indicate that emissions from vintage plastic pipe and modern plastic pipe are similar, but that infrequent very large leaks may be more prevalent for vintage plastic pipe. The differences in system performance between pipeline material categories is not easily discernable using individual leak location data; it is better assessed by evaluating system-wide leak rates per year (leaks per mile per year) for the various types of pipeline material vintages and categories.

6. Citations/References

1. GTI Final Report "Classification of Methane Emissions from Industrial Meters, Vintage vs Modern Plastic Pipe, and Plastic-lined Steel and Cast-Iron Pipe", DOE PROJECT NUMBER DE-FE0029061, GTI PROJECT NUMBER 22070, June 30, 2019
2. OTD. Improving Methane Emissions Estimates for Natural Gas Distribution Companies, Phase II – PE Pipes, OTD Report OTD-14/0001. 2013.
3. Palermo G. Correlating Aldyl "A" and Century PE Pipe Rate Process Method Projections with Actual Field Performance. http://www.janatechnology.com/whitepapers-correlating-aldyl-a, 2000.
4. "Operations Technology Development NFP. (2018). Research Project Summaries" https://www.otd-co.org/newsroom/Documents/OTD-Research-Project-Summaries-2018.pdf

2.13. Methane Emissions Studies - Buried Plastic & Unprotected Steel Main & Service Leaks (CARB) BP 20a AI-4.1 & 4.3

Sponsor: CARB (SoCalGas & SDG&E)
Status: Completed

1. Objective

This is a Research & Development (R&D) project that analyzed methane emissions from various distribution pipelines within the state of California.

The objective of this project was to evaluate and develop emission factors (EFs) for buried unprotected steel and plastic mains and services for California. This may improve the accuracy of the estimated methane emissions for natural gas distribution companies in California.

2. Background/Approach

California Senate Bill (SB) 1371 required the adoption of rules and procedures to minimize natural gas leakage from CPUC-regulated utilities to reduce the emission of greenhouse gases. Until recently, methane emissions were calculated and reported based on EFs that were developed in 1996 by the Gas Research Institute (GRI) and the Environmental Protection Agency (EPA); however, these emission factors are now outdated. Over the years, utilities have made improvements on system maintenance as well as the detection and mitigation of leaks. Additionally, field measurement instruments and protocols have changed since the completion of the 1996 GRI/EPA study. Therefore, EFs could be improved by collecting and analyzing more recent data.

The data collected for this study focused on non-hazardous leaks from buried unprotected steel and plastic mains and services in the SoCalGas, SDG&E, and PG&E service territory. Each leak site was detected using a combustible gas indicator (CGI) and measured using a Hi-Flow sampler. A bootstrap statistical analysis was performed, and a summary of the collected leak data is presented below:

CARB/GTI Data Number of Leaks	Unprotected Steel Mains (Qty)	Unprotected Steel Services (Qty)	Plastic Mains (Qty)	Plastic Services (Qty)
Original data				
Corrected data*				

CARB/GTI Data Ave. leak rate	Unprotected Steel Mains (SCFH)	Unprotected Steel Services (SCFH)	Plastic Mains (SCFH)	Plastic Services (SCFH)
GTI Mean				
SCG/SDGE Mean				
% Difference				

The data collected under this project was analyzed in comparison to the GRI/EPA study as well as the recent WSU/EDF study which also developed emission factors for distribution pipelines by material type on a national level.

3. Accomplishments

- Data collection and validation of material and facility categories have been completed for both SoCalGas and SDG&E.
- Leak repair data was provided to CARB/GTI for refinement of emission factors based on actual leaking pipeline material and facility.
- The draft final report containing leak data and project findings is reportedly under review by CARB.
- Comparing current leak data emissions to the estimated emissions using EFs developed under the 1996 GRI/EPA study indicates that there has been a reduction in average leakage rates, which should be reflected in the corresponding calculated EFs. However, due to the uncertainty with data from prior studies and the lack of reconciliation to repaired leak data for the correct categorization of leak data for the facility type (Main or Service) and material types any comparison should be viewed from a combined total leak data perspective for the respective materials considered in this study.

4. Next Steps

SoCalGas has completed development of Company-Specific Emission Factors for buried Mains and Services, which leveraged knowledge gained from this study. All on-gong associated work is noted in section 3.18. While the final report is still pending from CARB this project is considered complete.

5. Citations/References

1. *Methane Emissions from the Natural Gas Industry - Volume 9: Undergound Pipelines. 1996,* Gas Research Institute and Environmental Protection Agency, GRI-94/0257.25, EPA-600/R-96-080: United States.
2. *GHD Emission Factor Development for Natural Gas Compressors,* PRCI Catalog No. PR-312-16202-R02, April 18, 2018.
3. *Methane Emission Factors for Compressors in Natural Gas Transmission and Underground Storage based on Subpart W Measurement Data,* PRCI Catalog No. PR-312-18209-E01, October 17, 2019.

2.14. Spray-on Leak Seal for Meter Set Joints (OTD 5.18.a Phase 1) BP 23 AQ-1

Sponsor: Operations Technology Development
Status: Completed (Progressing to Next Phase)

1. Objectives:

The objective of this project was to identify and evaluate easy to apply leak sealant products that could be applied to the exterior of pressurized meter set assembly (MSA) piping with a leak rate up to 1.5 SCFH operating at pressures of 7" WC and 2 PSIG. This type of leak sealant solution would reduce the need to disassemble and reassemble MSAs to repair non-hazardous low-pressure gas leaks. The evaluation effort was to establish ease of use and permanency of the identified sealants.

2. Background/Approach

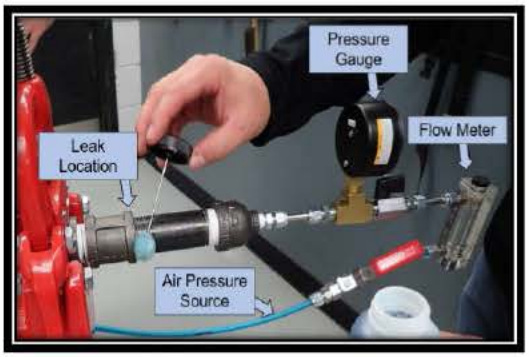
In collaboration with representatives from 8 different resin manufacturers, a total of 21 leak sealant products were identified and evaluated as potential solutions. The resin manufacturers included [redacted] The identified products were grouped by product type: epoxy paste, epoxy putty, silicone paste, spray and wraps. The epoxy putty type products tested favorably due to the thicker viscosity of this product type versus the pastes and sprays. The pastes and sprays were not able to seal the 1.5 SCFH leak rate at 7" WC. Most of the products tested are commercially available and rated for other applications, non-gas leak related. The resin manufacturers of those products that tested favorably as part of this project expressed their interest and willingness to reformulate their sealant resins to meet the needs of the natural gas industry.

3. Accomplishments

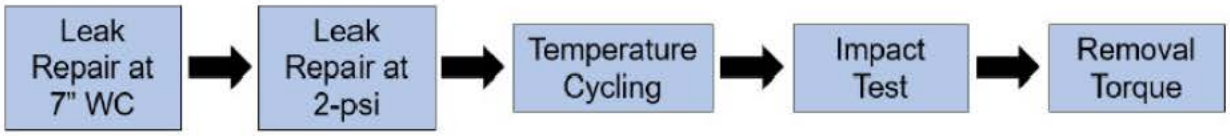
Short-term testing was conducting for each of the 21 leak sealant products. The short-term testing consisted of evaluating pipe joint preparation requirements, leak sealant application process, cure time of leak sealant product, ability to seal pressurized piping with a leak rate up to 1.5 SCFH operating at 7" WC and 2 PSIG, reaction of cured sealant product to leak soap solution, and reaction to gray enamel paint used by LDCs to protect MSA piping. 5 of the 21 leak sealant products successfully passed the short-term test. These 5 products were then tested to the long-term protocol which consisted of 10-day temperature cycling between -20°F and 140°F, performing an impact test, pressurizing the test assembly and confirming tightness test of threaded joint and leak sealant product, and measuring the torque required to disassemble the threaded joints with the leak sealant applied.

The 5 leak sealant products that successfully passed the short-term testing also passed the long-term testing.

Leak Test Apparatus



Leak Sealant Product Testing Workflow



Final Test Results of Successful Leak Sealant Products

Product Type	Product Name	7" WC Leak Seal Test	2 PSIG Leak Seal Test	Temperature Cycling Test [2 PSIG]	Impact Test [2 PSIG]	Torque Test
Epoxy Putty	[redacted]	Passed	Passed	Passed	Passed	Passed
Epoxy Putty		Passed	Passed	Passed	Passed	Passed
Epoxy Putty		Passed	Passed	Passed	Passed	Passed
Epoxy Putty		Passed	Passed	Passed	Passed	Passed
Epoxy Putty		Passed	Passed	Passed	Passed	Passed

4. Conclusions

Currently, an easy to apply leak sealant product for pressurized leaking MSA gas piping is not commercially available to the natural gas industry. However, this project did identify five epoxy putty type leak sealant products that successfully passed all short-term and long-term testing conducted by GTI. The identified leak sealant products are used successfully in industrial and automotive applications. These same leak sealant products also meet the needs of the natural gas industry. With minimal reformulation of these commercially available resins, a new resin could be developed and approved for the natural gas industry.

5. Citations/References

1. "Operations Technology Development NFP. (2018). Research Project Summaries" https://www.otd-co.org/newsroom/Documents/OTD-Research-Project-Summaries-2018.pdf

3. Active Projects

The following 22 projects are still in progress and active.

3.1. Storage Research Project (CEC GFO-16-508 Group 1) BP 16 Y-1

Sponsor: California Energy Commission (SoCalGas)
Status: Active

1. Objectives:

   The overall objective is to develop advanced risk assessment models including new tools, technologies, methods, methodologies, and approaches to improve underground natural gas storage infrastructure safety and integrity management in California.

2. Background/Approach

   This research consists of two separate projects with work conducted at Lawrence Berkeley National Laboratory (LBNL) and DNV GL.

   The overall goal of the LBNL project is to develop a risk assessment and management methodology and framework to improve underground natural gas storage security. While risk management is frequently considered a passive activity to guide future actions, the LBNL approach includes assessment models that are continuously updated by monitoring data. A schematic of the LBNL system is shown in Figure 1.

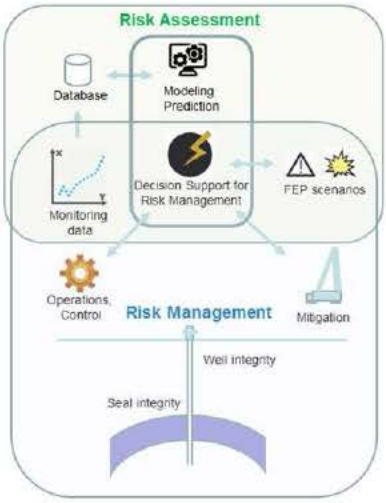


Figure 1. Schematic of LBNL System

The specific objectives include:

- Develop a set of analytical tools specifically designed to estimate the risk and evaluate mitigation strategies for underground natural gas storage infrastructure under various failure scenarios that are most relevant to California natural gas storage.

- Provide a scheme for using new and continuously updated monitoring data to update risk models or for early leakage/damage detection.
- Provide a supervisory interface to integrate all system components and form the framework to manage data (both site data and monitoring data), feed real-time data into the analytical tools for risk assessment, prioritize data collection, evaluate mitigation strategies, and provide the key information needed to support decision-making for operators and managers to make prompt recommendations for threat responses.
- Apply the proposed framework to one or more natural gas storage facility (e.g., the Aliso Canyon Gas Storage Facility) in close collaboration with SoCalGas.

The LBNL multi-disciplinary team has two parallel efforts: (1) One team will develop a set of models, test the models using synthetic data, then link the models within the supervisory interface. The interface will be tested by comparing the integrated model output to individual model outputs using synthetic examples; (2) The second team will work closely with SoCalGas to install advanced monitoring technology and acquire data. Then the two efforts will merge by demonstrating the developed framework at a SoCalGas site.

The overall goal of the DNV GL project is to demonstrate an advanced risk assessment methodology that can help anticipate, prioritize and manage pipeline threats in a comprehensive manner for assessing the safety and integrity of natural gas pipeline systems in the California. The objective is to provide methodology and a suite of tools that can be used by pipeline companies for improved integrity decision making.

The overall approach of the DNV GL project is four-fold:

- Customize Bayesian network models for external corrosion and mechanical damage
- Validate the models against field data from SoCal Gas Company
- From the model, develop leading indicators for pipeline integrity management
- Transfer knowledge and software tools to the pipeline company staff

3. Accomplishments

The LBNL project has completed the following tasks:

- Developed the geomechanical model
- Developed a wellbore model
- Completed a geo-hazard analysis
- Installed downhole monitoring devices (fiber optic distributed acoustic and temperature sensors, downhole pressure/temperature sensors) in the Honor Rancho demonstration well

Ongoing tasks in the LBNL project include:

- Calibration of the geomechanically model
- Continue developing the supervisory interface
- Testing via Use Case demonstrations

The DNV GL Risk Model Development project has completed all preliminary work. Ongoing tasks include validation of the model and preparing the final report.

4. Next Steps

The LBNL project completion timeframe is Q4 2020. The next steps include completing the ongoing tasks, completing field measurements and demonstrating the system.

The DNV GL project completion timeframe is June 2020. The next steps include validation of the model and preparing the final report.

5. Citations/References – *none at this time*

3.2. sUAS Technology Regulatory & Technology Assessment (NYSEARCH M2014-001) BP 17 Z-2

Sponsor: NYSEARCH
Status: Active

1. Objectives:

   This is a basic research and development project to integrate methane sensors into the small Unmanned Aircraft System (sUAS) flight control system and data management software to develop an aerial based leak detection system.

2. Background/Approach

   Aerial based systems can survey areas that present challenges to vehicular-based systems.
   - High resolution Imagery from UAS mounted camera systems of difficult to access locations of high-pressure aboveground pipeline can assist in providing valuable information about the integrity of the pipeline. This allows for early detection of corrosion or missing coating that can be remedied before it results in the occurrence of a leak.
   - The aerial based leak detection technologies are expected to provide an alternative in instances where walking and vehicle-based survey are not practical. This should allow for the detection of leaks in previously inaccessible areas while localization abilities would reduce the incidents of false positive allowing for better productivity gains in emission reduction. The control software being developed for these technologies should optimize the analytics of the data collection to allow for leak pinpointing accuracy in a user-friendly package.
   - Once these stages are complete, field testing under various environmental conditions is expected to provide sufficient data to help determine if the technology can produce acceptable pinpointing accuracy in a timeframe reasonable for the task. In addition, false positive/ negative rates will need to be evaluated. Potential impact on system emissions, emission factors, or inventory cannot yet be determined.

3. Accomplishments

   A localized module has been produced that is capable of mounting onto an UAS for leak detection. This module was tested in a controlled environment for its effectiveness and efficiency in leak detection and localization.

   Field Trials were completed in residential neighborhoods at National Fuel, SoCalGas, and BG&E. A dual sensor configuration was demonstrated at SoCalGas using the JPL OPLS

methane sensor to monitor atmospheric methane enhancements (parts per billion sensitivity) and the [redacted] methane sensor for emission source localization and pinpointing (parts per million-meter sensitivity). An image of the SoCalGas sUAS configured with dual methane sensors is shown in Figure 1. An example of the map produced by the sUAS survey is shown in Figure 2. Each field trial was followed by refinement and development of data algorithms, flight procedures, hardware and software to improve software automation and data interpretation.

Figure 1. SoCalGas sUAS with dual methane sensors

[redacted]

Figure 2. Residential Emission Survey Heat Map

4. Next Steps

A final report and analysis of all field trial data is being compiled and anticipated for issue to NYSEARCH funding members in 2nd Qtr 2020 along with access to software. Preliminary review of results demonstrates the system has some capability of detecting and localizing emissions; however, more data analysis will be required and possibly field trials. Once the final report and software is released SoCalGas will determine next steps and make a Go/NoGo decision in light of other projects and advancements in sUAS technologies.

5. Citations/References:

1. PR-459-133750-R03 Fast, Accurate, Automated System to Find and Quantify Natural Gas Leaks https://www.prci.org/Research/SurveillanceOperationsMonitoring/SOMProjects/ROW-3H/6080/172025.aspx
2. Small Unmanned Aerial Systems (sUAS) Regulator & Technology Assessment Technology Brief, NYSEARCH http://dev.nysearch.org/tech_briefs/sUAS_Reg_and_Tech_Assessment.pdf

3.3. Aerial (sUAS) Leak Detection Research projects (SCG-2016-001) BP 17 Z-3

Sponsor: SoCalGas/SDG&E
Status: Active

1. Objectives:

   This is a development project to develop methane emission leak detection, source location and leak pin-pointing from a small Unmanned Aerial System (sUAS), with the resulting data integrated into the Leak Survey Business Process targeting applications in remote areas or populated areas with limited or constrained accessibility.

   If the technology is successful at reliably detecting methane emission leaks, locating the source of the leak, and pin-pointing the leak location then standard operating procedures (SOP) can be developed for performing leak investigations and/or compliance leak survey operations. The resulting procedure must also be in compliance with regulations governing flight operations of UAVs, such as Federal Aviation Regulation (FAR) Part 107 and other state and local jurisdictional requirements.

   Due to the dynamic nature of the development of these systems, there are additional drone/sensor combinations that may be recommended for future investigation based upon the knowledge and experienced gained during this project.

2. Background/Approach

   The sUAS or "drone" based methane detection industry is rapidly changing and advancing. This project was initiated in 2016 and the project has been executed in parallel with, and in support of the progressive development of drone and sensor instrument by the respective manufacturers. The aircraft, sensor payloads, and data collection and integration into the flight management systems must all be harmonized and can place constraints upon both the detection capabilities of the sensor along with flight operations.

   The continued RD&D approach to meet the project objectives is a series of planned evaluations:

   1. Controlled Evaluation - the sensor is tested in a controlled environment to determine the operating parameters against manufacturer specifications.

   2. Controlled Field Study - the prototype system (UAV with sensor payload) is tested in a controlled environment for its effectiveness and efficiency in methane emission detection, source localization, and leak pin-pointing capabilities. Ground verification of a methane emission source is mandatory prior to declaration that the methane

source is a system leak and subsequent leak grading due to the many other possible methane sources in the environment. False positive and false negative methane detections are assessed.

3. Controlled Evaluations – Controlled releases and known leaks are used to test system capabilities at various sites and under varied conditions. False positive and false negative methane detections are assessed.

4. Leak Survey Field Trials – the sUAS is used as the initial detection tool as part of the Leak Survey process. Leaks are verified and graded. False positive and false negative methane detections are assessed.

3. Accomplishments

The [redacted] sensor was integrated onto various UAV platforms and flight control systems. Multiple controlled release studies and field demonstrations were completed:

- Controlled Evaluations were executed at three SoCalGas facility locations. --
- Controlled Field Demonstration – Controlled field demonstrations with methane releases were successfully completed at four separate locations, two of which were residential neighborhoods and one business district area. The residential and commercial surveys were completed with the support of local city officials and public services departments.
- Leak Surveys Demonstrations – 3 leak survey demonstrations have been completed Finalize Data Management and Post Processing - through many iterations the data processing has been refined to quickly parse extraneous data points from the raw data stream, which enables rapid production of accurate heat maps for use in ground verification of emission source detection and grading in the case of system leaks.
- Results from a series of controlled and uncontrolled applications at test sites and in the field demonstrated accuracy (location of leak) and consistency (leaks detected) in the performance of the system (see test examples, below).
- In January 2020 SoCalGas staff formally approved the current sUAS [redacted] sensor for integration during Leak Survey and Leak Investigations in remote and difficult-to-reach applications.

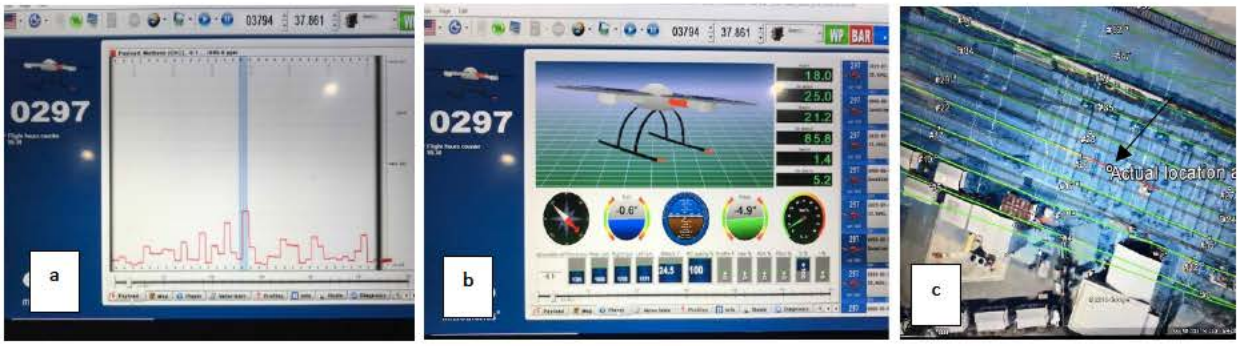


Figure 1. Example of data from drone graphically, (Figure 1a), drone attitude (Figure 1b) and leak location using Google Earth (Figure 1c).

During the latest controlled release double-blind evaluation of the SoCalGas sUAS the leak survey accurately detected and located all of the controlled leaks and no additional leaks were found other than those identified by the sUAS leak survey. Leaks were located by ground crew using soap testing and measured for flow rate. Leak flow rates detected by the sUAS leak survey range from 0.03 to 1.84 scfh.

Figure 4 shows several examples of the results of soap testing. Two of the leaks, Figure 4a and 4b, were controlled leaks, intentionally created for the survey. These leaks were measured to be 1.49 and 0.53 scfh. The third leak, Figure 4c, is an as-found leak, measured to be 0.03 scfh.

Figure 4. Simulated/Controlled Leaks (a) and (b), (c) Actual leak detected and located by sUAS leak survey and verified by ground crew.

4. Next Steps

A next generation methane sensor is expected to be available in Q2 2020. Unlike the original sensor, this sensor is specifically designed to interface with a drone. This sensor will be integrated into a newer UAV and flight management system. The evaluation and steps outlined above, (Controlled Evaluation, Controlled Field, Field Demonstration, Create SOP, Data Management and Post Processing and Pilot Test), will be executed on the new system.

5. Citations/References – *None at this time*

3.4 Aerial Leak Detection - Manned Aircraft (SCG-2019-012) BP 17 Z-4

Sponsor: SoCalGas/SDG&E
Status: In-Progress

1. Objectives:

   This project is to evaluate and demonstrate the capabilities of technologies for leak detection, localization, and pin-pointing using manned aerial systems. The targeted applications are for use as a screening tool for un-surveyed Distribution service areas that are not surveyed in a given year; or for use in conjunction with Distribution leak survey; or as a compliance leak survey technology for Transmission pipelines in unpopulated areas.

   The expected outcome of this project is to gain an understanding of the capabilities of commercially available aerial leak detection services that have not yet been tested or vetted for theses specific use-cases in Distribution applications. This project and associated pilot studies will also be used to evaluate the cost effectiveness in reducing natural gas emissions.

2. Background/Approach

   SoCalGas evaluated and approved the [redacted] leak detection system for aerial leak survey of Transmission pipelines in unpopulated areas in 2016. The technology was tested using controlled releases that were unknown to the technology provider, both in the location and size. Successful demonstration of the system capabilities resulted in implementation in 2017. The Company has since been using the [redacted] technology successfully as part of the Transmission leak survey process in certain unpopulated areas, with a 98% true-positive emission detection rate.

   There are currently many other service providers offering aerial-based leak detection technologies with varying stated capabilities. This project will evaluate various technologies that appear to have the potential to offer a cost-effective means for reducing natural gas emissions.

   A tiered methane emissions detection strategy has been widely discussed where aerial methane emissions technologies are employed to cover large areas rapidly to detect the larger emission sources in the environment, which augments traditional routine leak survey practices that are very effective at detecting ground-level and underground methane emissions in order to effectively manage pipeline safety and the leak-migration threat. In 2019 SoCalGas identified the [redacted] technology as a viable technology to evaluate for various use-cases in populated Distribution service areas, as well as a potential additional technology for the leak survey use-case for transmission pipelines in unpopulated areas. The [redacted] technology does not claim to be

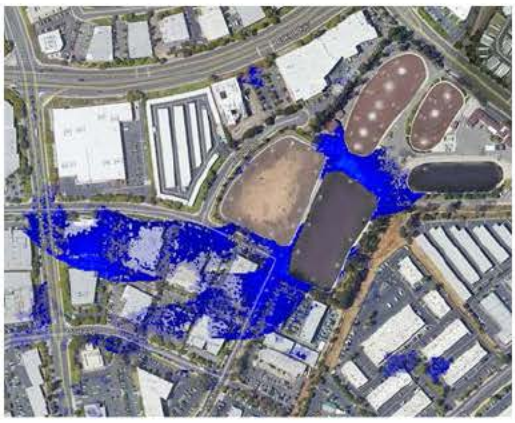
able to detect small leaks (1 SCFH and less) that make up a large proportion of the leak population from the Distribution system. Rather, the [redacted] technology claims reliable detection for emission sources with flow rate 25 SCFH or larger; however, the system can detect leaks as small as 1 SCFH given favorable conditions. Therefore, the target Distribution application is for use as an incremental technology to the many existing leak detection activities for the purpose of identifying the larger sources of methane emissions within the service territory.

3. Accomplishments

In the 4th quarter of 2019, SoCalGas conducted an initial study of the [redacted] system covering a 12 square mile area containing an estimated 365 miles of Distribution Mains and Service and 26,246 customer meters over a two-day period. Such densely populated Distribution areas result in a complex methane environment due to many potential sources of methane emissions aside from the Natural Gas pipeline distribution infrastructure.

During the flight operations, SoCalGas also performed a series of simultaneous controlled methane releases ranging from 0 to 45 SCFH to verify the ability of the [redacted] technology to detect and in some condition approximate the leak flow rate. All controlled releases were detected and localized correctly, and 95% of controlled release source locations were accurately pin pointed. None of the zero release locations were falsely detected (performed since ground activity can be visually observed). The flow rate estimation data capabilities are still being analyzed to calculate the [redacted] flow rate estimation performance.

Within this initial study area all locations where a point-source methane plume was detected were investigated. Emissions source investigations included leak investigation on the gas distribution system (where appropriate), and in cases where the methane plume was detected on customer property and possibly due to natural gas use, leak investigations were conducted by working with the customers.



Methane plumes from a
Waste-water Treatment Plant

Methane plumes from
fertilizer mounds near a golf course

In some cases, other sources of methane (such as Oil and Gas production facilities, Waste treatment facilities, various industrial and commercial facilities, vehicle emissions, and natural biogenic and petrogenic sources) were determined through analysis of aerial imagery and ground verification activities.

In the 1st Quarter of 2020, SoCalGas conducted additional pilot studies. To date, the pilot study has covered an additional 45 square miles of Distribution service area containing an estimated 1,289 miles of Distribution Mains and Services and 96,090 customer meters. As a result of this project, additional insight is being gained as to the varied sources of methane emissions within the operating environment. Preliminary ratios for quantity of point-source methane plume categories:

- ~60% were traced to either leaks on customer piping systems or from customer equipment that had high emissions (downstream of the Company meter)
- ~18% could not be located (likely due to non-persistent or mobile sources)
- ~14% were from leaks on the Company piping distribution system
    - ratio of large leaks (leak flow rates of 10 SCFH or larger) were an order of magnitude higher than the ratio detected during normal leak survey due to the technologies detection bias toward larger emission sources
- ~8% were from a variety of other methane sources (e.g. Industrial production/processing, naturally occurring biogenic and petrogenic sources, agricultural, and vehicle emissions).
  Note: percentages represent number of sources not emission volume ratios. More source data is required to develop emissions volume ratios for these categories.

With technology that allows for visualization of methane plumes other insights are gained that can help explain why ground-based mobile methane mapping methods have high "false-

positive" detection rates. Such systems have been focused primarily on detection of leaks from the Company piping system. The influence of wind, including vertical displacement relatively close to the emissions source can be clearly demonstrated by looking at plume data under different conditions. The example below shows a methane plume from a boiler on the roof of a two-story building. The image on the left shows the plume with the wind blowing from right to left, which drove the emissions plume to the ground level. The image on the left 1 day later shows the wind ~180° in the opposite direction. The source of this emission plume is properly depicted at the top of the building.

4. Next Steps

The pilot study is planned to continue through 2020 covering different types of operational areas and use-cases. It is expected that this study will adequately assess the capabilities and probabilities of detection in various operating environments of this technology, including emissions quantification. The pilot study is also evaluating and developing preliminary business process workflows needed to respond to the data volume and information needed to estimate cost effectiveness.

Other less sensitive aerial technologies are also being considered for deployment at higher altitudes with more rapid area coverage to facilitate a tiered approach to support the Utilities emissions reduction strategy.

5. Citations/References – *none at this time*

3.5. Below Ground Methane "Background" Concentration Study Research Projects (SCG-2018-003) BP 17 AB-1

Sponsor: SoCalGas / SDG&E
Sub-Project Sponsor: PHMSA 748 with Colorado State University and University of Texas at Arlington
Status: Active

1. Objectives:

   The overall project objective is to understand the conditions and mechanisms affecting gas migration from pipeline leakage. This project is to develop an analytical model to predict the conditions needed for gas migration. With an evaluation of all the pipeline variables, an investigation into the operating conditions of the ambient environment and a study of the impact of the soil types through pedology, this model is intended to assist in the decision making to determine whether below ground methane measurements are indicative of a leak from the natural gas piping system. The model is intended to be used to recommend efficiency improvements for identifying buried pipeline leaks, and the variables that increase the risk for leak migration.

2. Background/Approach

   In order to account for the conditions and mechanisms affecting gas migration from pipeline leakage, an analytic method will be developed to predict the conditions needed for gas migration. From this work, recommendations on improving efficiency in finding leaks are intended to follow from the analytic model development.

   The overall project has five aspects:
   - Controlled Field Experiments (METEC)
   - Numerical Modeling
   - Controlled Field Experiments (METEC) Low-cost Sensor System
   - Survey Tool
   - Field Visit to Validate Model.

   This is a collaboration among Colorado State University (CSU), University of Texas, PHMSA and Industry with the CSU principal investigators providing the approach and strategy.

3. Accomplishments

   In support of the PHMSA project, SoCalGas has provided soil samples and survey data from pipeline leak repair sites to facilitate the development of the analytical model.

It has been determined that detection of average-sized leaks at a distance of 6 inches (15 cm) above the ground requires the minimum detection limit (MLD) of a methane detection technology to be 10 ppm methane or below.
The understanding of the behavior of this complex system is growing through the linking of numerical models with controlled experiments.

Figure 1(B.) illustrates the experimental results of gas dissipation in air. At low wind conditions (<2 m/s) there is substantial dissipation (from 100 ppm to 20 ppm) within the first 10 cm (4 inches).

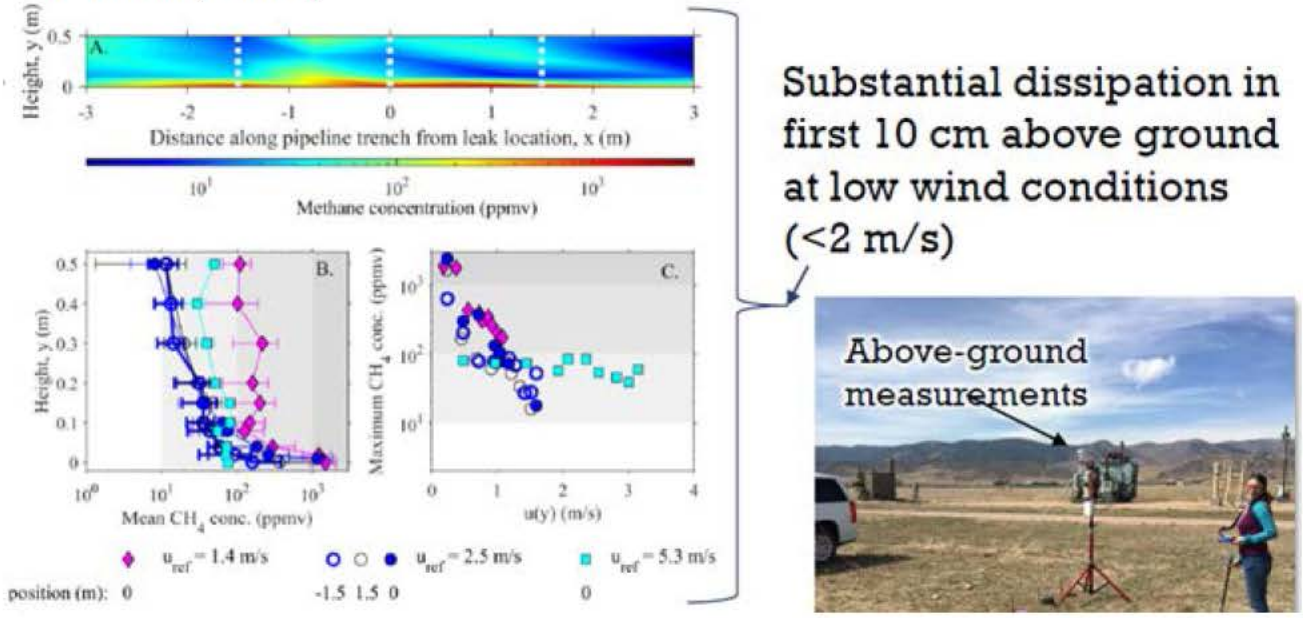


Figure 1. Experimental Results of Gas Dissipation in Air

Figure 2 illustrates the experimental results of gas migration in earth with detection of leaks ranging from 3 to 9 liters per minute (LPM). The leak location and buried pipeline are represented by the * and | respectively. The methane concentration is illustrated by the color map ranging from 10 to 10,000 ppmv.

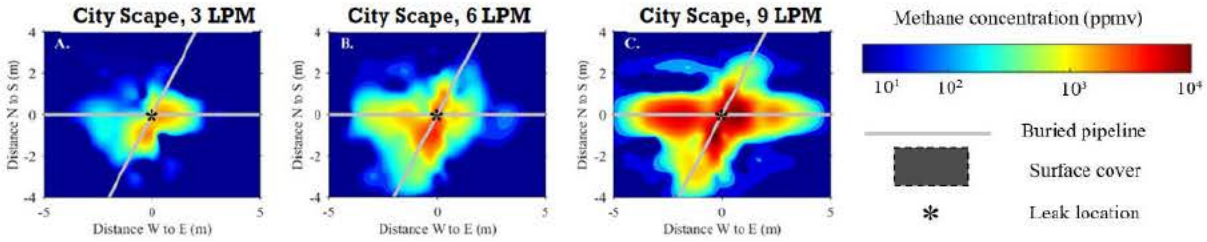


Figure 2. Experimental Results of Gas Migration in Earth

Figure 3 illustrates a preliminary model output of the effect of windspeed on gas migration. It is a demonstration vehicle and will be refined with further iterations.

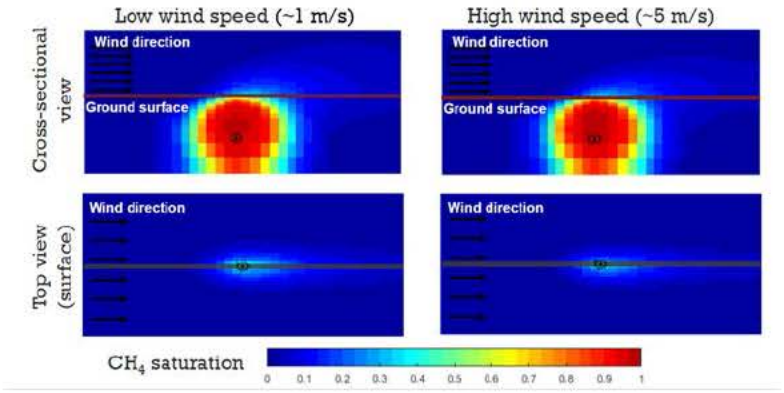


Figure 3. Numerical Gas Migration Model Simulation

4. Next Steps

Given the complexity of this system, there are many open questions about gas migration and accurate quantification of leaks. Currently, the PHMSA Project is working to develop the numerical models to predict gas migration behavior above and below ground under a wide range of field conditions.

5. Citations/References –

1. Oldenburg, Curtis M., and André AJ Unger. "COUPLED SUBSURFACE–SURFACE LAYER GAS TRANSPORT AND DISPERSION FOR GEOLOGIC CARBON SEQUESTRATION SEEPAGE SIMULATION." In Tagungsbeitrag, TOUGH Symposium, pp. 12-14. 2003.
2. Okamoto, Hideki, and YasushiroGomi. "Empirical research on diffusion behavior of leaked gas in the ground." Journal of Loss Prevention in the Process Industries 24, no. 5 (2011): 531-540.
3. Ha, Seung-Wook, Byeong-HakPark, Seung Hyun Lee, and Kang-KunLee. "Experimental and numerical study on gaseous CO2 leakage through shallow-depth layered porous medium: implication for leakage detection monitoring." Energy Procedia 114 (2017): 3033-3039.

3.6. Back Pack & Handheld Methane Detection Tools (Sensor) & Systems Research Projects (SCG-2018-004) BP 17 AC-2

Sponsor: SoCalGas/SDG&E
Subproject: NYSEARCH (T-784)
Status: Active

1. Objectives:

   This is a basic Research & Development project to investigate handheld parts per billion (ppb) detection level instruments as possible enhancements to the current walking leak survey methodology which utilizes a parts per million (ppm) detection level instrument known as [redacted]. Advanced handheld methane detection technologies can detect enhancements in background atmospheric methane levels within the vicinity of a pipeline leak and may be able to assist in detection and localization of leaks on the distribution system during walking-leak survey.

   The expected outcome is to reduce the number of false negatives when field personnel conduct walking leak surveys. The addition of backpack and handheld ppb level methane sensors in the leak survey process is intended to incrementally improve the probability of detection of a leak. The intent is to couple the atmospheric (ppb level) methane sensor output with the output of the ground-level methane concentration (ppm level) data for walking leak surveys.

2. Background/Approach

   Backpack and handheld methane detection technologies with a wide range of detection sensitivities were identified and acquired for evaluation. This include one (1) with a 1 ppb detection level, and two (2) with a 100 ppb detection level.

   The sensors to be tested for accuracy and evaluated against each other and in coordination with a DPIR unit for accuracy. Detailed test plans for both controlled laboratory environments and simulated field environments were developed, and test plan execution is pending. The test methodology includes evaluation of the following:

   - Sensor performance: Compare the response of a sensor to a controlled leak relative to no leak (or ambient methane) conditions.
   - Sensitivity to leak location: Determine the sensor response to controlled leaks across a range of distances from the leak source (vertical and horizontal).

- Sensitivity to ambient conditions: Determine the sensor response to controlled temperature changes (Laboratory). Record wind conditions (simulated field testing), ambient temperature, and relative humidity during all testing.
- Baseline stability: Quantify instrument drift (i.e., changes in the background methane reading) during the test period.

Additionally, a parallel effort was initiated with NYSEARCH in 2019 known as the "First Pass Leak Detection" project. The goal is to optimize use of instrumentation and data acquisition techniques to maximize the detection of pipeline leaks predominantly for walking survey (and augmented by other strategies) to achieve maximum leak detection in one pass by utilizing both PPM and PPB instruments in combination. The testing protocols will be determined by a funder working group, selecting various instruments with both (ppm and ppb detection levels) and techniques for performing the leak detection, followed by field testing at 3 different funder sites. Each test would build on lessons learned from the previous test leading to a final optimized process of leak detection

3. Accomplishments

The results of the initial Controlled Laboratory Testing (2019) and initial Simulated Field Testing (2019) were incorporated into follow-up test plans (2020). Figure 1a and 1b are examples of the Simulated Field Testing.

Figure 1. Backpack PPB Methane Detector (a) Handheld PPB methane sensor (b)

This second round of Controlled Laboratory and Simulated Field Testing includes lessons learned from the previous work in addition to the inclusion of alternate technologies.

The Controlled Laboratory Test Plan was completed Q1 2020 and testing is scheduled for Q2 2020. This testing will include side-by-side evaluation of the three instrument's responses to both methane and ethane at selected temperatures and concentrations.

The Simulated Field Test Plan was completed Q1 2020 and testing is scheduled for Q2 2020. This testing will include measuring the methane response to a near-ground level, controlled leak at four distinct leak rates, during the single pass of a walking leak survey at four distinct distances from the leak. All three instruments will be tested simultaneously and integrated with ground-level ppm survey data.

Regarding the "First Pass Leak Detection Project", the commercially available instrumentation was evaluated. [redacted] (ppm instrument similar to the [redacted]) and [redacted] (ppb) detectors were selected for the project as both include the integration of software with mapping capability which will assist in the compilation of data required for the evaluation. These units are in the process of being obtained.

4. Next Steps

The Controlled Laboratory Testing and Simulated Field Testing are scheduled for Q2 2020. Following the execution of these tests, the results and analysis will be reviewed and described in a Controlled Laboratory Testing Report and Simulated Field Testing Report, anticipated late Q2 2020. The results of these tests will guide the preparation of Field Testing, anticipated Q3 2020.

Regarding the "First Pass Leak Detection Project", the test protocol is being developed and will be submitted to the funders in Q2 2020 followed by field testing and statistical analysis of the data.

5. Citations/References – *None at this time*

3.7. Integrate Mobile Methane Mapping w/ Mobile Leak Survey Research Project (SCG-2018-005) BP 17 AD-1

Sponsor: SoCalGas/SDG&E
Status: Active

1. Objectives:

   This is a basic research and development project to evaluate the possibility of integrating wind and GPS information, as captured by the [redacted] with the traditional methods of OMD and Mobile DPIR. This project will also continue the on-going effort to improve utilization of mobile methane mapping data and explore possible integration with Advanced Meter processes for the detection of leaks downstream of the meter on customer facilities.

2. Background/Approach

   The traditional method for mobile leak surveys is the optical methane detector, OMD. The vehicle is driven along right-of-way (transmission pipelines, high pressure distribution pipelines, and Distribution Mains) at speeds between 10 and 35 mph. The OMD system does not currently capture or utilize GPS and wind data.

   The Mobile DPIR is also company approved for mobile leak surveys and does not capture or utilize GPS or wind data. The Mobile DPIR is rated for 5 mph.

   The proof of concept and field data collection includes mobile mapping of a pre-determined route in Pico Rivera on a monthly basis to monitor the background methane level in the atmosphere and evaluate potential benefits of integrating background atmospheric methane data, GPS, and/or wind data into traditional mobile leak survey technologies.

   The initial step is to baseline the OMD and the Mobile DPIR. The 3 technologies are installed on and integrated into a single vehicle. Evaluations during this exploratory phase include the baseline detection limits and accuracy (false positives with respect to identifying natural gas emissions coming from SCG facilities) for each technology alone and integrated as a whole.

   The result of this project will be a Phase I report with a Go/No-Go decision whether wind and GPS data should be integrated with the traditional mobile leak survey applications. The integration of wind and GPS data into the leak survey process is expected to increase the understanding of the results of leak surveys. If successful, recommendations for the development and integration of these technologies for mobile leakage surveys may be developed.

3. Accomplishments

This project is exploratory in nature, so it is expected that follow-up questions and requirements will need to be examined to be able to evaluate these technologies effectively.

Key considerations for this research include defining baselines, determining the effect of the data integration between sensor technologies and data from other sensors (GPS, Wind). The Pico Study Area that is utilized for this project is shown in Figure 1. The following has been established:

- Route and Study Area Constraints (Pico Study Area)
- Data Collection and Communication Methods
- Time Frame for Route Execution

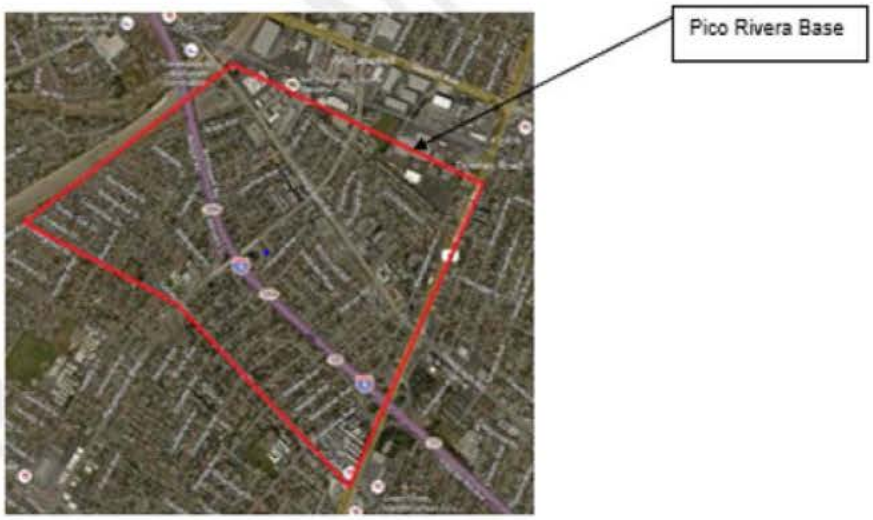


Figure 1: Pico Study Area, Pico Rivera

Figure 2: Mobile Methane Mapping Vehicle

- Data Analysis

In general, the Mobile Methane Mapping system, as tested, did not have a high detection rate of known system leaks within the Pico Study Area.

The results of this project demonstrated that the Mobile Methane Mapping produces some false positive indications. In contrast, the Company traditional leak investigation surveys produce very few false positives, which is also demonstrated through this project.

The plot grid below (See Figure 3) shows the [redacted] emissions detection system results within the Pico Study Area with respect to known and detected Company and Customer leaks for 2019. The gray line shows two sharp peaks at the beginning and at the end of the year – this line represents the indications produced by the [redacted] system as potential methane sources. This is compared to the lines for the number of confirmed leaks from both the Company system and Customer leaks. This data appears to demonstrate a sensitivity of the system to seasonal variation in atmospheric methane levels. Further, the trends of emission indications and detected leaks fail to follow the trends of Company and Customer leaks, and at times show decreasing trends while Company and Customer leaks increased.

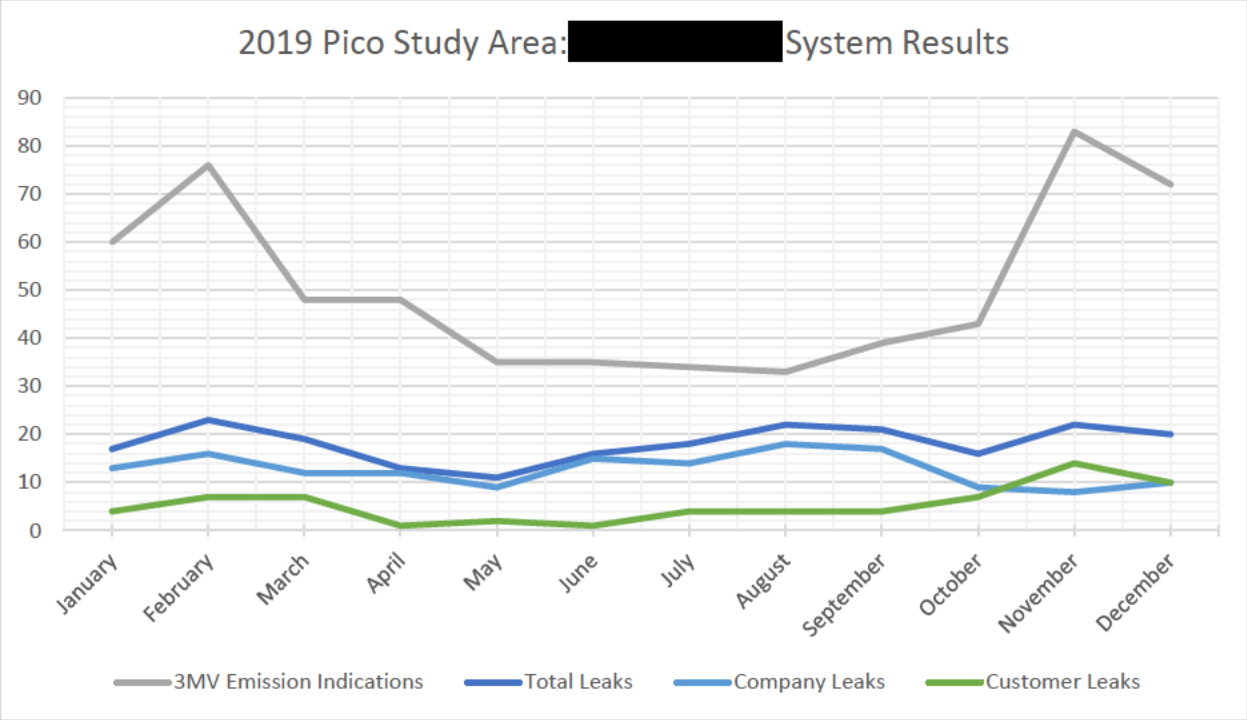


Figure 3: Plot Grid

4. Next Steps

Continue data gathering and analysis is needed through 2020 prior to making a Go/NoGo decisions on the value of enhancing traditional mobile leak survey system with additional sensor data.

The monthly mobile methane mapping and Leak Survey activities continue with changes in day-time vs night-time drive protocols to observe the effect on leak detection rates of both known and potential new leaks.

5. Citations/References

1. https://www.socalgas.com/regulatory/documents/r-15-01-008/EDF_4-Cities_Methane_Mapping_Report_Final_081916.pdf
2. https://primis.phmsa.dot.gov/rd/mtgs/091118/Ed%20Newton.pdf
3. https://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=8467

3.8. Evaluation of "Point and Shoot" Methane Detection Technologies (OTD 7.18.f) BP 17 New-1

Sponsor: Operations Technology Development
Status: Active

1. Objectives(s):
   The stated objective for this project was to:

   "Test the effectiveness of laser-based 'point and shoot' methane detection tools to identify leaks. GTI will evaluate how well these instruments perform compared to standard handheld CGI type sensors for initial leak identification and how well they perform relative to each other."

2. Background/Approach

   Laser-based point and shoot instruments can be used to conduct leak surveys. They offer potential advantages over traditional walking leak surveys by: 1.) minimizing the amount of walking and time needed to survey large areas; and 2.) allowing personnel to efficiently complete inspections in restricted areas (due to fencing, marsh areas, ravines, etc.). For SoCalGas, the primary application of interest for the point and shoot instruments is to detect leaks from customer meters and regulators.

   The primary project tasks to evaluate point and shoot instruments were:

   - Controlled Field Testing
   - Leak Facility Field Testing
   - Background material tests, through-glass/window tests, and rain tests

   Testing was conducted with five handheld laser-based sensors: [redacted] that was considered the benchmark detector.

3. Accomplishments

   The controlled field testing for above ground leaks was conducted at two nominal leak rates, a "high" leak rate of 15 to 19 scfh and an "low" leak rate of 3 to 8 scfh, from a gas meter assembly. The testing was conducted at multiple instrument-to-leak distances along 4 transects from the leak source. For underground leaks, a single walking survey was conducted at a sand pit leak site with 4 of the 5 sensors for a single "large leak". Qualitative evaluations of the sensors' portability, durability, and ease of use were conducted. Background material tests (brick, concrete, wood painted white, wood painted black, white

plastic, black plastic, white siding, blue cinder block wall, untreated wood, mirror, rusty sheet metal, and shaved ice), through-glass/window tests, and rain tests were conducted.

Figure 1 compares the responses of the different instruments as the distance to the leak source increases, and the response varies by distance.

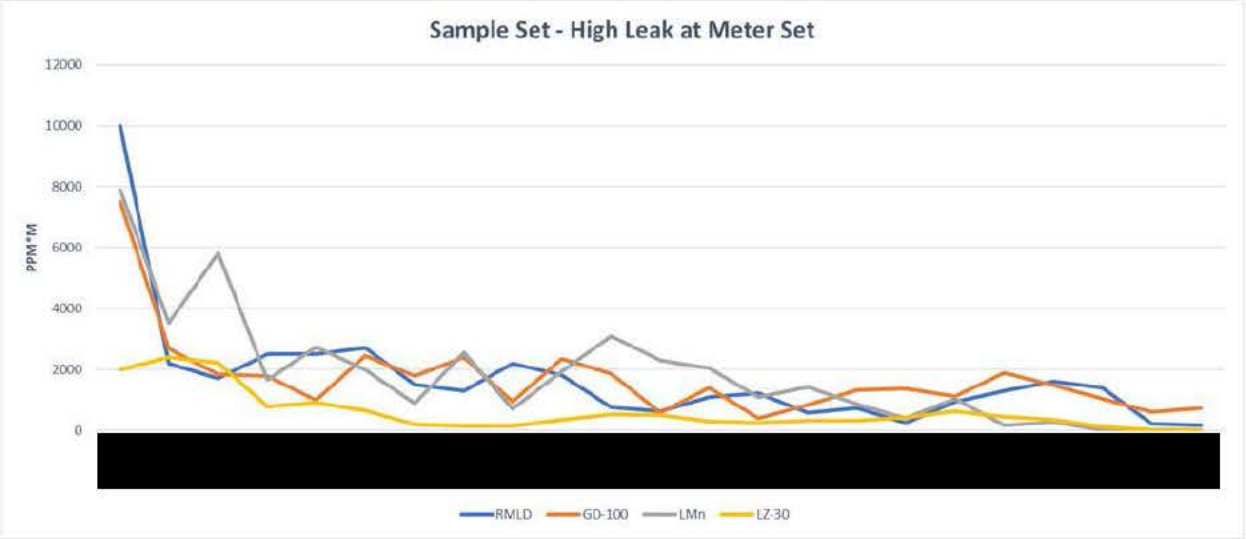


Figure 1. Impact of distance to emission source on instrument response

Figure 2 compare the responses of the instruments to different background materials. Lighter color and more reflective materials resulted in higher responses.

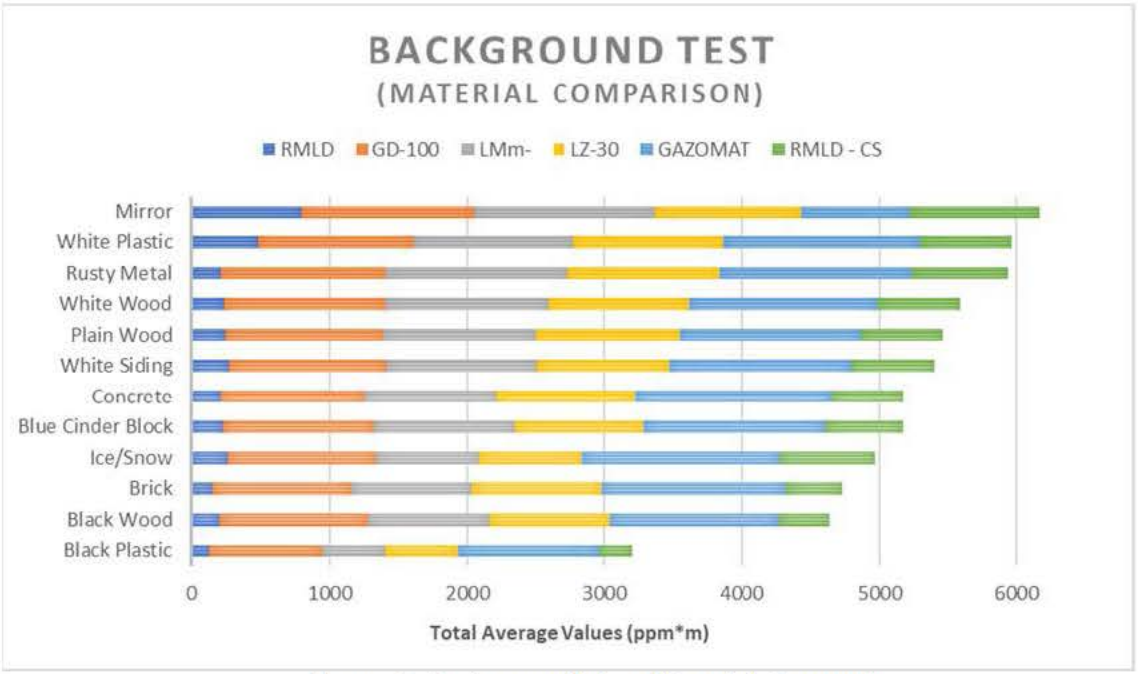


Figure 2. Background Test-Material Comparison

4. Next Steps

Final report estimated completion the end of 1st Quarter 2020.

5. Conclusions

The testing was conducted at leak rates that are much higher than measured at customer meters. In the l report for GTI/OTD Project Number 7.17.d "Methodology to Estimate Flow Rate of Above Ground Leaks Using a Soap Test", it is noted that GTI and CARB found that the average leak size on a residential meter set in California is about 0.005 scfh. The 1996 GRI/EPA Methane Emissions study measured an average leak size on residential customer meters of about 0.078 scfh. Thus, the leak rates used for the controlled field testing were about two to three orders of magnitude greater than average size leaks found on the equipment of interest (i.e., customer meters and regulators). Additional testing (with smaller leaks) would be needed to determine if the instruments could be used by SoCalGas to reliably detect leaks (i.e., determine the operating envelopes for sensors considering leak rate, sensor-to-leak distance, and wind speed).

6. Citations/References

1. "Operations Technology Development NFP. (2018). Research Project Summaries" https://www.otd-co.org/newsroom/Documents/OTD-Research-Project-Summaries-2018.pdf

3.9. Residential Methane Detector (NYSEARCH M2010-002) BP 18 AE-3.1

Sponsor: NYSEARCH
Status: Active

1. Objectives:

   The project objective is to develop a residential methane detector using an advanced methane sensor developed by Applied Nanotech, Inc. (ANI). ANI has developed a robust, low cost, miniature methane (natural gas) sensor based on Micro-Resonator technology that uses a tuning fork to measure the viscosity of a gas mixture. Due to its high reliability and resistance to false alarms, this sensor was slated for the residential sensing application.

2. Background/Approach

   Instruments available in the market that measure concentration of methane and/or combustibles vary in accuracy, range, price, and calibration needs. Typically, low cost sensors suffer from reliability and robustness issues, resulting in many false positive alarms. Sensory technologies have advanced in the last decade. NYSEARCH identified the micro-resonator technology, developed by ANI, as a technology able to provide all the features needed. In addition, certain jurisdictions like New York City are developing plans to require the use of natural gas detectors in multi-family homes.

   The project comprises of five Phases:

   1. Feasibility study
   2. Development of a benchtop instrument
   3. Development of an analytical instrument followed by a pre-commercial prototype for residential applications
   4. Pilot testing program
   5. Improve any technical issues identified in Phase 4

Turning Fork Used in Micro-Resonator

Residential Methane Detector installed adjacent to gas water heater

3. Accomplishments

Phases 1 to 4 have been successfully completed.

Phase 4 - Deployed 171 detectors with nine companies in multiple geographic areas to assess their performance and reliability. Approximately 130 units have been returned and the overall condition seems to be very good. Also, overall response at alarm setting appears to be good. A number of units were going into an alarm state with no apparent leak present. The sources of false alarms were identified, and software updates were made to correct the problem. However, two concerning issues were identified through post-pilot test analysis pertaining to drift of the sensor.

Phase 5 investigated the issues encountered in Phase 4 and discovered that the prototype sensor drift could mask a very slow build-up of methane (methane concentration increase of less than 3% per day) from being detected. Three approaches were pursued to address the drift issue: enhanced conditioning of detectors at time of manufacturing, gold plating of the

tuning fork, and drift correction algorithm enhancements. Unfortunately, none of the approaches proved successful. Commercially available residential methane sensors tested alongside prototype units did not appear to experience the same problem. After all avenues to find a solution were exhausted a decision was made to terminate the project.

4. Next Steps – To be determined

5. Citations/References – *None at this time*

3.10. Residential Methane Detector (OTD 1.14.g.4 - PHASE III) BP 18 AE-3.2

Sponsor: Operations Technology Development
Status: Active

1. Objectives(s):

   The stated objective for this project was to:

   "Test a set of residential methane detector (RMD) devices from three different manufacturers to determine initial responses to methane gas, to generate preliminary performance statistics, and to show their stability to extremes of temperature and humidity in accordance with protocols outlined in the UL standard for RMDs."

2. Background/Approach

   The stated overall business value for this project was:

   "The results of this research will allow utility companies to add to their environmental and safety public awareness programs by offering technically validated information regarding the reliability and enhanced safety that in-home methane detectors might provide."

   Phase 3 R&R (Repeatability & Reproducibility)[5] testing evaluated "high-performing" residential methane detector (RMD) devices[6] from three different manufacturers [redacted] to determine initial response to methane, to generate preliminary performance statistics, and to evaluate their stability when exposed to extremes of temperature and humidity.

3. Accomplishments and Results

   The study included RMD devices manufactured in the years 2011 to 2015; however, for all three manufacturers the majority of the devices (i.e., 85+%) were from one year. The initial response to 25% LEL methane was evaluated for a total of over 1,200 RMD devices from the three manufacturers. The initial responses to 5% and 10% LEL methane were evaluated for a total of about 225 RMDs from the three manufacturers. The impact of temperature (0°C - 49°C) and relative humidity (RH) (0-5% to 91-95%) were evaluated for a total of about 25 RMDs from the three manufacturers. Numerous devices were tested to provide data to evaluate reproducibility; however, replicate testing of single devices to

[5] The OTD/GTI 2015 Proposal defines Repeatability as "the ability to provide consistent readings on a single device", and Reproducibility as "the ability to achieve consistent results on multiple devices."
[6] The high-performing devices were identified during the Phase II testing

evaluate repeatability was not conducted.

The table below summarizes the results of the initial response tests. The [redacted] devices had the best performance.

Manufacturer	Percent of RMD Devices Responding to Various Methane Concentrations		
	25% LEL	10% LEL	5% LEL
[redacted]	100%	99%	88%
[redacted]	100%	45%	0%
[redacted]	99%	0%	0%

The temperature and RH tests were short term tests (e.g., the detectors were exposed to the nominal stated atmospheric conditions for a minimum of three hours to ensure that thermal equilibrium was achieved prior to exposure to methane) and following these tests the RMDs were thermally re-equilibrated and retested. Long-term testing of the sensors was not conducted. The general results of the temperature and RH testing show:

- the sensors in the RMDs may not respond well to a low temperature extreme (0°C);
- the sensors in the RMDs may have problems after exposure to a high temperature extreme (49°C);
- some of the sensors in the RMDs may not respond well at low humidity (0-5% RH), particularly at low methane concentrations;
- some of the sensors in the RMDs may not respond well at high humidity (80-90% RH) at lower methane concentrations. Condensation on the sensor may be the cause of the poor response; and
- some, but not all, of the sensors used in the RMDs may experience issues at high humidity (91-95%) plus high temperature (38-42°C) at lower methane concentrations.

4. Next Steps

Complete pilot study and issue final report.

5. Conclusions

For SoCalGas, this project most directly aligns with Best Practice #18 "Stationary Methane Detectors" in the SoCalGas SB 1371 Compliance Plan. Best Practice #18 addresses the use of stationary methane detectors for early detection of leaks at natural gas facilities and

locations such as compressor stations, terminals, gas storage facilities, city gates, and metering & regulating stations. The devices evaluated by this testing are designed for indoor residential methane monitoring and, while they may have utility for such an application, they may not be sufficiently robust for outdoor industrial applications.

6. Citations/References

1. "Operations Technology Development NFP. (2018). Research Project Summaries" https://www.otd-co.org/newsroom/Documents/OTD-Research-Project-Summaries-2018.pdf
2. OTD Reports & Summaries available at: https://www.otd-co.org/reports/Pages/default.aspx
3. Evaluation of Residential Methane Detectors, Phase 2 - OTD Project Number: 1.14.g
4. Residential Methane Gas Detector Testing Program, Phase 1 OTD Project Number: 1.9.h
5. Residential Methane Detectors Program - Reliability and Reproducibility Task Report, Phase 3 OTD Project Number: 1.14.g

3.11. Stationary Methane Sensor Evaluation (SCG-2017-011) BP 18 AE 3-3

Sponsor: SoCalGas/SDG&E
Status: Active

1. Objectives:

   This is a basic Research & Development project to evaluate and demonstrate capabilities of new and advanced stationary methane detection and monitoring technologies with a wide range of detection sensitivities. Advanced stationary methane monitoring systems may demonstrate the ability to remotely monitor an area of interest to provide early notification of leakage at above ground facilities. And to determine the application(s) best suited for each technology.

   The expected outcome is to gain an understanding of the capabilities of commercial stationary methane sensors from both a practical and performance perspective, and to provide recommendations for further testing and deployment.

2. Background/Approach

   Stationary methane detection and monitoring technologies with a wide range of detection sensitivities were identified and acquired for evaluation. This includes Infrared Optical point sensors, with a 2% LEL (1,000 ppm methane) lower detection limit, and Tunable Diode Laser Absorption Spectroscopy (TDLAS) open path sensors with less than 1 ppm lower detection limit.

   The project is segregated by technology where the point sensors are tested and evaluated against each other and the open path sensors are tested and evaluated against each other. Detailed test plans for both controlled laboratory environments and simulated field environments were developed and executed. In addition, select sensors were deployed for Field Pilot Study.

   For the Laboratory and Simulated Field Testing, several characteristics were examined to evaluate the methane emissions detection capabilities of the sensors:

   - Sensor performance: Compare the response of a sensor to a controlled leak relative to no leak (or ambient methane) conditions.
   - Sensitivity to leak location: Determine the sensor response to controlled leaks across a range of distances from the leak source (vertical and horizontal).

- Sensitivity to ambient conditions: Determine the sensor response to controlled temperature changes (laboratory testing). Record wind conditions (simulated field testing), ambient temperature, and relative humidity during testing.
- Baseline stability: Quantify instrument drift (i.e., changes in the background methane reading) during the test period.
- Relative performance: For each of the evaluation criterion, the performances of the different test units [redacted] were compared.

For the Field Pilot Study, the approach is to install detection technologies at 10 above ground M&R Regulator stations with inlet pressures above 300 psig. Once installed and operational, the emissions will be monitored during normal operations including investigation of all alarm conditions. To gather comparative leak detection data, controlled emissions testing will be performed.

At the conclusion of the monitoring period a general summary report will be prepared detailing pilot results by technology with recommendations for an appropriate course of action.

For the Field Pilot Study, the core success measure is the contribution to emissions reduction. In addition, equipment and operational costs will be evaluated to develop the cost effectiveness of the approach. Supporting criteria include the following:

- Projected Installation Cost (materials, labor)
- Projected O&M Costs (sensor/battery replacement, calibration, fix-on-fail events, network data transmission)
- Impact of site variability on cost estimates
- Frequency and cost of investigation "investigation, including "false positive" leak alarms and "false negative" missed leaks
- Accuracy and timeliness of leak detection for each technology in comparison to current leak survey practices

3. Accomplishments

The Controlled Laboratory Testing and Simulated Field Testing portions of the project are complete. The Simulated Field Testing set-up is shown Figure 1. A comparison of the response of an open-path sensor during the Controlled Laboratory Testing and during the Simulated Field Testing is shown in Figure 2. Key findings from these tests include:

- Performance degradation (or non-operation) at temperature extremes. The [redacted] point sensor and [redacted] open path laser demonstrated degradation at hot temperatures (120◦F). All open path lasers demonstrated degradation or failure at cold temperatures (20◦F).
- Background drift with certain technologies
- At nominal environmental conditions point sensors displayed a limited range of detection (depending on distance from source)
- At nominal environmental conditions, open path sensors perform their basic function, which is to indicate elevated methane levels during a gas leak

The Controlled Laboratory Testing and Simulated Field Testing Reports are in final review Q1 2020.

Figure 1. Simulated Field Testing Open Path Units Aimed at Reflectors

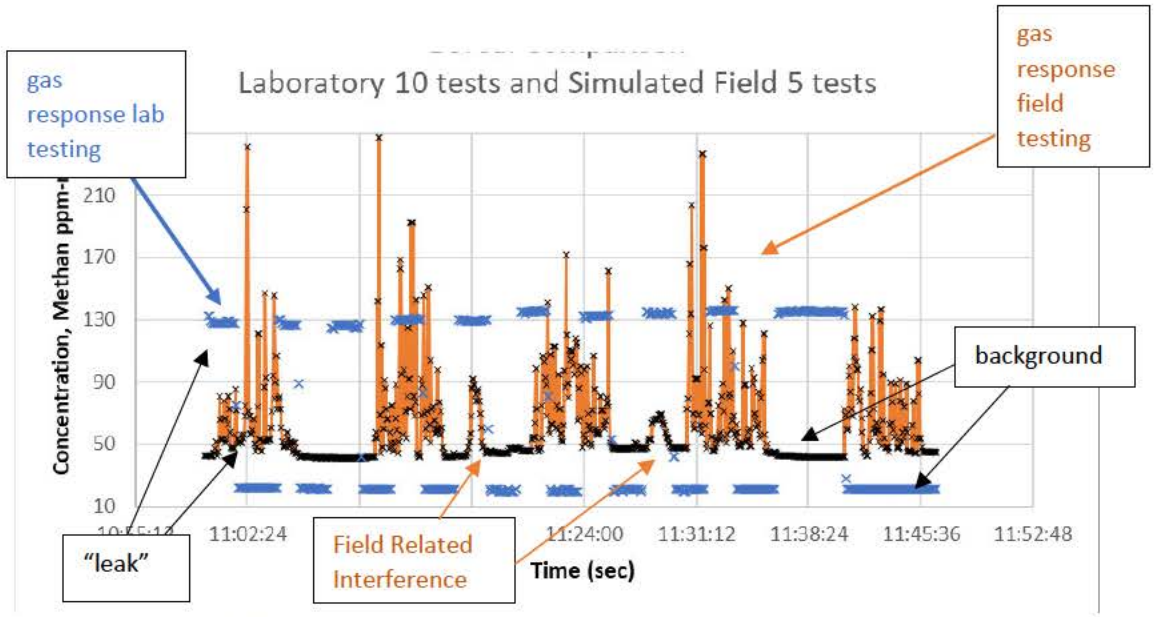


Figure 2. Overlay of Results of Simulated Field Test and Controlled Laboratory Test for an Open Path Laser

The Field Pilot Study construction is complete at all sites. Two of the three open path lasers have been successfully commissioned. There are persistent challenges with data stabilization and communication. The team has applied, and continues to apply, a range of remediation approaches.

4. Next Steps

A project summary evaluation is being prepared to determine the strategy for further controlled testing.

The Field Pilot Study monitoring will continue to triage the communication performance and data collection challenges of two of the open path laser technologies while monitoring ongoing operations. Continued deployment under the pilot study will be evaluated from a cost-effectiveness and emissions history for the various Distribution M&R Station categories and performance of company facilities based on the Distribution M&R Stations emissions report.

The team will begin commissioning activities on the third open path laser technology, followed by triage and remediation of any communication issues, and finalizing of data collection requirements.

5. Citations/References – *None at this time*

3.12. Gas Imaging- Testing of Multi-Sensor Gas Imaging Camera (NYSEARCH M2018-002) BP 17 New-2

Sponsor: NYSEARCH
Status: Active

1. Objectives:

   This project is an evaluation of Gas Imaging Cameras. For underground leaks, the goal is to establish the detection limit, demonstrate the ability to image and quantify emissions flux, and demonstrate the ability to assist with leak pinpointing in areas where there may be multiple leaks.

   The objectives of the project are to:

   - establish the detection limit of the current [redacted] camera prototype for underground leaks from the distribution infrastructure;
   - demonstrate the ability of the prototype to image and quantify emissions flux of underground leaks; and
   - demonstrate the ability of the camera to assist with leak pinpointing in areas where there may be multiple leaks.

2. Background/Approach

   The evaluation approach includes a series of Simulated Field Tests to demonstrate and assess the ability of the camera system to detect, image and quantify emissions of underground natural gas leaks over a range of controlled release rates and pipeline pressures, in ambient environmental conditions.

   In addition, the approach includes establishing an estimate of the uncertainty of the measured emission flux relative to the actual release rate, as a function of standoff distance and wind conditions.

   Finally, the approach is to establish the minimum emission flux that can be detected by the camera system and Q-chamber, under operating conditions typical for gas utility companies in different parts of the country.

   The evaluation also includes real-world cases of grade-3 leaks. The goal is to demonstrate and assess the ability of the camera system to assist with leak pinpointing in with multiple adjacent areas (or boreholes) of gas emissions from the ground. Tests are proposed to be performed in conjunction with utility work crews in the field.

3. Accomplishments

Field testing with the [redacted] camera prototype was completed at SoCalGas in April 2019 and at Spire Alabama in July 2019. Results from the two field tests showed limitations in the stated capabilities of the MSS non-thermal imaging camera. NYSEARCH funders agreed to a round-robin type testing with another optical gas imaging camera currently on the market. Testing with the [redacted] gas imaging camera was completed at SoCalGas in October 2019.

Fig.2 - Accessory quantification "Q-Chamber"

4. Next Steps

A final report is being compiled to evaluate both technologies for emissions detection and pinpointing applications and is anticipated to be distributed Q2 2020.

5. Citations/References – *None at this time*

3.13. Develop a Recommended Practice (RP) for Transmission Leak Survey (PHMSA 22420) BP 17 New-3

Sponsor: PHMSA/GTI
Status: Active

1. Objectives:

   To develop a recommended practice (RP) for external based leak detection on natural gas transmission lines. The RP is intended to increase the safe operation of the U.S. natural gas transmission pipeline network by standardizing practices across operators and increase the likelihood a leak is found before becoming a safety hazard.

2. Background/Approach

   The approach to achieve the overall objective to develop an RP for external based leak detection consists of three tasks.

   Task 1. Assess the current body of knowledge on leak detection from natural gas transmission pipelines by compiling current operating procedures from specific companies and existing RPs, identifying specific leak detection use cases for individual companies, and creating a technology review document.

   Task 2. Develop standardized sensor specifications, test procedures, and a Certification Organization Framework by using existing framework documents to finalize recommended sensor test procedures, conducting evaluations of current technologies and establishing sensor performance specifications, and producing recommendations for a technology certification organization.

   Task 3. Compile knowledge in a single location and produce an RP document that summarizes recommendations and is distributed to end users/operators.
   An example of the organization of the multiple types of detection, sensors, methods, platforms is illustrated schematically in Figure 1.

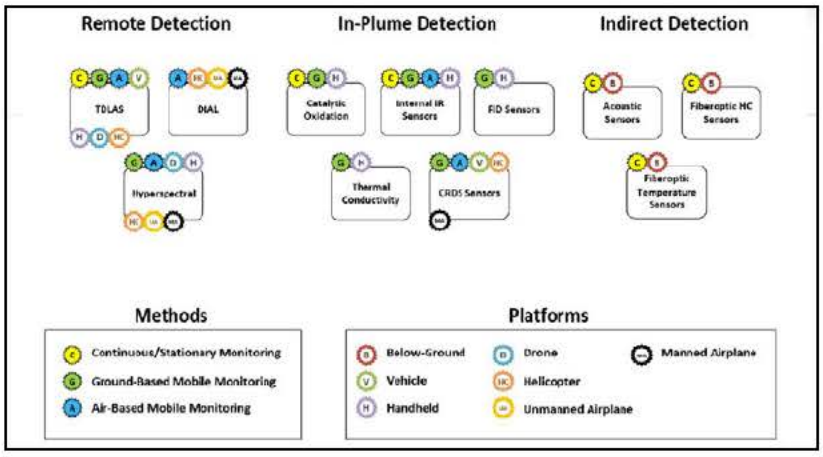


Figure 1. Organizing Information

3. Accomplishments

From Task 2, above, "Establish Standardized Sensor Specifications and Testing Practices", and "Develop Certification Organization Framework" are complete.

The human factor has been determined to have a significant role throughout the leak detection process through:

- Selecting the correct instrument for the job.
- Tuning the instrument to a balanced setting
- Developing clear protocols for leak alarm response
- Training

4. Next Steps

Develop the recommended practice.

5. Citations/References

1. API RP 1175, "Leak Detection Program Management," API, 2015.
2. Henrie, M. P., et al., Pipeline leak detection handbook., Gulf Professional, 2016.
3. PHMSA, "Pipeline Safety: Control Room Management/Human Factors," Final Rule, 2010.
4. "ANSI/ISA 18.2-2016 Management of Alarm Systems for the Process Industries," ISA/ANSI, 2016.
5. "API RP 1165 Recommended Practice for Pipeline SCADA Displays," API, 2007.

3.14. System Emissions Using Mass Balance with Advanced Meter Technology Research Project (SCG-2018-006) BP 20a AF-1

Sponsor: SoCalGas
Status: In Progress, Delayed

1. Objectives

   This project is to assess the feasibility of developing algorithms designed for early detection of Distribution System Leaks using a mass-balance approach and leveraging natural gas consumption data from the Advanced Meter (AM) network within a defined study area.

2. Background/Approach

   Conceptually, the volume of natural gas entering a defined portion of Distribution Mains and Services should equal the combined volume of natural gas delivered to Customers within the defined area plus the volume that passes through the system, with the difference attributed to vented and fugitive emissions. However, as is the case with current "Lost and Unaccounted For" studies there are many other variables that must also be considered, such as measurement errors, temperature factors, temporal variation in meter reads and accounting errors. As the scale of the system being considered shrinks in size some of these variables can be controlled and/or adjustments made to the mass balance calculation. In addition, machine learning technologies already being applied by SoCalGas can also be leveraged in a data intensive application. This project will leverage the gas consumption analytics and machine learning currently used for the purpose of detecting leaks downstream of the Advanced Meter technology.

3. Accomplishments

   Potential project areas were identified and evaluated against initial project criteria.

4. Next Steps

   Plan and install measurement meters on Mains feeding a selected project area.

5. Citations/References:

   1. https://www.cpuc.ca.gov/uploadedFiles/CPUC_Website/Content/Safety/Risk_Assessment/Methane_Leaks/5.%2011-16-18%20LUAF,%20Sempra.pdf
   2. https://www.aga.org/policy/state/natural-gas-state-profiles/state-info/unaccounted-for-natural-gas-in-the-utility-system/

3.15. Quantification of Small Leaks and Define Practical Lower Emission Threshold Research Project (OTD 7.17.d) BP 20a AH-1

Sponsor: Operations Technology Development
Status: Active

1. Objectives:

The stated objective for this project was to: "To evaluate a methodology using a soap test to characterize/estimate the flow rate of a leak on above ground assets at 60 psig or less."

The original scope of this project was to determine the point at which the flow rate is too large for bubbles to form when sprayed with leak solution. After initial tests, this scope was updated to include a study of bubble formation at flow rates between 0.003scfh and 5 scfh.

An additional objective is to develop Leak-Based Emission Factors on above-ground assets at 60 psig or less.

2. Background/Approach

In 2012 PHMSA implemented the Distribution Integrity Management Program regulations requiring reporting of leaks as either "Hazardous" or "Non-Hazardous", including MSA leaks. In accordance with this, minor leaks were not required to be reported to PHMSA.

At that time, SoCalGas/SDG&E conducted laboratory tests to validate AGA guidance regarding "seen, heard, or felt" criteria, and correlation with "blowing-off of leak detection soap". This work resulted in the determination that soap bubbles begin to be blown-off at approximately 4 cfh +. In addition, the work validated the rapid dissipation of natural gas above-ground and that use of the soap test criteria offered a good safety factor for concerns with above ground accumulation. The implementation of the policy resulted in an increase in the number of reported non-hazardous leaks. See Figure 1.

SB-1371	"Hazardous"		"Non-Hazardous"		Total	
Report	(Qty)	(%)	(Qty)	(%)	(Qty)	Notes
2015	2,503	7.3%	32,019	92.7%	34,522	Implemented policy changes
2016	3,025	4.4%	65,009	95.6%	68,034	
2017	2,791	4.1%	65,282	95.9%	68,073	
2018	2,913	4.2%	67,145	95.8%	70,058	

Figure 1. Impact of Policy Changes on number of reported Non-Hazardous Leaks

This approach to meet the objectives and scope of this project includes:

Soap Solution Identification/Procedure Review The type of soap, concentration and mixing techniques for soap tests in the field can vary widely. Based upon a survey of project sponsors for commonly used soaps, and procedures for mixing, a list of 3 soaps and concentrations will be identified.

Initial Lab Testing of Leak Rates and Soap Bubbles The test matrix includes leak flow rate (0.003 to 28 scfh), soap solutions (3 types), and thread type (bare, doped, taped). The size of leak orifice, wind conditions, and atmospheric temperature are controlled and constant.

Follow-up Lab Testing Utilizing the lessons learned in the initial lab testing, further tests will investigate the relationship of low flow rates with foam/bubble formations in a lab setting.

Develop Leaker Based Emission Factors Based upon the results of the testing, develop preliminary emission factors.

3. Accomplishments

Initial testing that was completed in 2019 demonstrated that good correlation exists between soap bubble size and leak flow rate. This work also demonstrated that practical bubble size categories could be used to develop leaker-based emission factors.




Miniscule Small Medium Large

[---- Defer Repair -----][----------Non-Hazardous----------][------ Hazardous-----]

Laboratory testing at different flow rates was completed. Tests up to 0.014 SCFH contained primarily foam with some small bubbles forming periodically. Small bubbles in photo formed at 0.082 SCFH. Medium bubbles in photo formed at 1.0 SCFH. Soap solution began to be blown off at 4+ SCFH. The average leak rate of for the "Miniscule" leak category is 0.003 SCFH. If blowdowns are required to repair a "Miniscule" leak the leak repair should be bundled with the next scheduled maintenance requiring blowdown to improve both emissions reduction and cost-effectiveness. These types of miniscule leaks are typically stable over time, and potential leak growth can be managed through subsequent inspections.

4. Next Steps

- Obtain consensus on categories and develop preliminary emission factor estimates.
- Complete final report for the OTD project.
- Perform in-house leak measurements to improve dataset for company-specific EFs

5. Citations/References

1. "Operations Technology Development NFP. (2018). Research Project Summaries" https://www.otd-co.org/newsroom/Documents/OTD-Research-Project-Summaries-2018.pdf

3.16. Research Leak Data Variables for Identification of Potential Large Leaks and Develop Preliminary Methodology to Triage Leak Data for Repair Prioritization (SCG-2017-009) BP 20a AI-3

Sponsor: SoCalGas/SDG&E
Subproject: GTI (7.19.d)/NYSEARCH (M2019-002)
Status: Active

1. Objectives:

   The objective of this project is to develop an approach for identifying and differentiating leaks on the buried distribution system that have high flow leak rates characterized by a leak rate of 10 CFH or greater, for the purpose of prioritizing repairs and reducing natural gas emissions from the distribution system. By reducing the number and duration of higher emitting non-hazardous leaks, actual emissions can be reduced and the approach for identifying and differentiating leaks is expected to result in a more accurate demonstration of emissions reductions.

2. Background/Approach

   Prior industry studies suggested that the number of system non-hazardous leaks that have a high flow rate, $\geq$ 10 scfh, is a small percentage of total leaks yet accounted for 80% of the system emissions. Based on the assumption that the flow rate population distribution of non-hazardous leaks in the SoCalGas system is similar to the study results, SoCalGas began to work on an efficient approach to identify the large flow rate on non-hazardous leaks, so they can be prioritized in the repair schedule.

   The approach is to leverage traditional walking survey leak data to identify potential large emitting leaks within the distribution system and minimize the number of leaks in the field which need to be measured for flow rate. The assumption is that existing system data about the leaks obtained at the time the leaks are detected and graded could be leveraged to identify a sub-set of all system leaks that had the greatest probability of being high flow-rate leaks. Since leaks that are categorized as a safety hazard (“Code 1” or “Grade 1” leaks) are identified and fixed immediately, studies focused on the non-hazardous leaks (“Code 2 or 3” leaks) that are generally scheduled for later repair or monitored, and thus can continue emitting for a period of time.

This required development of a decision tree to triage leak data from recent leak surveys to identify leaks with greatest likelihood of being a large leak. Surface expression measurements are performed on those leaks that are identified as having the potential to be a large leak, and leak rates that are measured as large are prioritized to reduce the time-to-repair.

3. Accomplishments

Phase 1 consisted of pre-screening over 300 code 3 pending leak locations, collecting methane surface concentrations levels along with associated description of the location of this emission (i.e. grass, crack, water meter box, etc.). Of the 300 locations, 157 were selected for direct emission rate measurements utilizing the high flow sampler. Trend analysis was then performed on the concentration levels relative to the location of the emission and correlated to the associated emission rates. Methane concentration thresholds for specific site conditions were then derived for segregation of potential high emitters ≥10 scfh. Preliminary threshold values for concentration measurements by surface condition type are:

- [redacted]

This methodology was termed the "Decision Tree" (DT) approach. The applicable concentration measurements are compared to the threshold values, and any one (or more) of the up to four concentration measurements that meets or exceeds the threshold concentration value will then result in that leak being measured for flow rate. If the flow measurement is greater than 10 SCFH then the leak is classified as a large, non-hazardous leak. Leaks measured larger than 6 SCFH are prioritized for repair in order to reduce emissions.

The results confirmed that the population of large leaks within the dataset was indeed a small percentage of the population (less than 5%) even though attempts were made to select the larger leaks in the system.

Figure 1. Leak Site Prescreening (Left), Surface Expression Measurement (Right)

Phase II effort was a pilot study within the service territory of three Company Districts to evaluate and validate the effectiveness of the decision tree concentration thresholds in identifying the high emitters in the population. A random sampling across the entire Service Territory of the Gas Company was conducted.

As of 11/22/19 Methane surface concentration levels were provided by the operating district personnel/contractors for 356 leak sites as part of their leak survey/investigation process. Of these, the Decision Tree was triggered for measurement 44 times from which 4 of the expected 7 large leaks were identified. Without applying the Decision Tree, to find the same ratio of 4 out of the 7 large leaks, on average would require the measurement of 203 leak rate samples out of the 356 leak sites.

The Decision Tree (DT) approach is 460% more efficient at finding the same number of large leaks relative to not using the DT process; thereby demonstrating the DT is an efficient screening mechanism.

In order to validate and achieve high statistical confidence in the DT model output, a statistical and probabilistic data analysis study was commenced with the data above as well as a collection of leak flow data based on a geographically diverse random sample of the entire SoCalGas distribution system (OTD 7.19.d).

Additionally, parallel projects were initiated with both NYSEARCH (M2019-002) and internally in 2019 to improve upon the leak quantification measurement method used for surface expression measurements by developing prototypes that improves upon the accuracy of the commercial systems

4. Next Steps

   The Phase II pilot will be extended through the end of 2020 to expand leak data and optimize decision tree prior to full implementation in 2021. Improvements in the leak quantification measurement method will also be evaluated (NYSEARCH M2019-002).

5. Citations/References –
   1. https://www.gti.energy/wp-content/uploads/2019/09/CH4-09a-Sep18-Ed-Newton-presentation.pdf
   2. *2019 Emission Factor Pilot Study.* Gas Institute Technology. Manuscript Submitted for Publication.

3.17. Methane Emissions Studies - Distribution Mains & Services (SCG & SDG&E) BP 20a AI-4.5

Sponsor: SoCalGas/SDG&E
Subproject: Operations Technology Development (OTD 7.19.e)
Status: Active

1. Objectives

   This is a Research & Development (R&D) project to develop company-specific emission factors (EFs) for buried Distribution Mains and Services. The OTD sub-project objective is to develop a framework that utilizes statistical approaches for properly sampling system leaks to develop company company-specific emission factors (EFs) for a variety of facility types, and the statistical and probabilistic mathematical approach for calculating the EFs. The SoCalGas dataset and approach has been provided as a case study for the OTD project.

   The expected benefit of this project is to provide more accurate estimates of a Company's system. Better estimates of emissions empower operators to make better decisions on where to focus mitigation efforts to effectively reduce methane emissions.

2. Background/Approach

   Company-specific EFs offer the means to accurately quantify methane emissions reductions from company facilities, allowing for a way to demonstrate the benefits of emission reduction programs. The value of producing company-specific EFs is that it allows for proper apportioning of mitigation efforts to the most cost-effective use of resources and provides for a defensible emissions reduction estimate. In addition, company-specific EFs provide accurate and consistent reporting of emission inventories.

   The following will be determined and implemented throughout this project. First, situation-specific sampling methods will be selected; this determines how a company physically measures their equipment's emission rate. The equipment, precision, and accuracy when measuring an emission rate will also be established. Next, a population-focused sampling plan will be developed which will include what variables should be recorded, how many samples are needed, and how the population of leaks will be categorized. While collecting leak information, statistical and probabilistic analysis techniques to calculate the EF from sample data is performed. A framework of the entire process along with specific examples of use will be provided from the OTD project.

3. Accomplishments

For buried mains and services, the leak flow measurement work conducted under project BP 20a AI-3 Prioritization of Large Leaks was leveraged to develop a set of Company-specific emission factors for SoCalGas as shown in the table below:

Situation Number	Field Situation Description	Emission Factor
1	Measured concentration triggers DT < 10 scfh category & leak rate is not measured (which would be the typical situation) - Use DT Not Triggered Ave EF	2.27 scfh
2	Measured concentration DT ≥ 10 category & leak rate is not measured (used when leak rate cannot be measured, such as leaks quickly repaired or when leak is in a remote location) - Use DT Triggered Ave EF	7.37 scfh
3	Leak repaired and no concentration or leak rate measurements - Use Combined All Case Ave EF	4.30 scfh
4	Measured concentration(s) trigger DT >10 category & then leak rate measured and actual leak rate is < 10 scfh - Use the actual leak rate measurement for the emission factor	Use actual leak rate measurement
5	Measured concentration(s) trigger DT >10 category & then measure and actual leak rate is ≥ 10 scfh - Use the actual leak rate measurement for the emission factor	Use actual leak rate measurement

- SoCalGas also discovered that "material" (e.g., plastic vs. steel, etc.) and "facility" (e.g., service vs. main) data did not appear to help in predicting large leaks, as demonstrated in a study with CARB. These results appear to further the need to develop Company-specific emission factors.
- OTD project proposal to develop the methodology to determine Company-based EFs was completed and project kickoff meeting was held.
- A stratified random sample method has been used to sample leaks in SoCalGas' service region. Bayesian probability techniques have also been used to establish a minimum, statistically significant sample size.
- Bayesian analysis to generate probability distributions of emission rates followed by a bootstrap procedure to provide confidence intervals has been explored.
- The combination of Bayesian analysis, bootstrap resampling, and distribution fits has been combined to calculate EFs.

4. Next Steps

- For buried mains and services leaks in the SDG&E service territory, a similar study to the BP 20a AI-3 Prioritization of Large Leaks will be conducted.
- Review commercially available sampling methods and develop a method selection guideline which incorporates feedback from utilities.
- Develop sampling approaches for field measurement surveys, which cater to different equipment types and geographic region.
- Implement a probabilistic data analysis approach for generating representative EFs and their uncertainties.
- Document a framework/standardized approach for planning, collecting, analyzing, and validating data to establish company-specific emission factors.

5. Citations/References

1. *2019 Emission Factor Pilot Study.* Gas Institute Technology. Manuscript Submitted for Publication.
2. *Methane Emissions from the Natural Gas Industry - Volume 9: Undergound Pipelines. 1996,* Gas Research Institute and Environmental Protection Agency, GRI-94/0257.25, EPA-600/R-96-080: United States.
3. *GHD Emission Factor Development for Natural Gas Compressors,* PRCI Catalog No. PR-312-16202-R02, April 18, 2018.
4. *Methane Emission Factors for Compressors in Natural Gas Transmission and Underground Storage based on Subpart W Measurement Data,* PRCI Catalog No. PR-312-18209-E01, October 17, 2019.

3.18. New Mobile Methane Quantification Technologies Research Projects (SCG-2018-010a) BP 20a AJ-1

Sponsor: SoCalGas/SDG&E
Status: Active

1. Objectives:

   This project is an evaluation of a mobile-based methane quantification technology. The [redacted] system is commercially available. This exploratory work will evaluate this technology for the ability to quantify the flux rate of non-hazardous methane emissions in an urban environment.

   The [redacted] system will be evaluated against a test plan and field tested for:
   - Comparison with manufacturer specifications
   - Comparison with traditional quantification technologies that are not mobile based (Hi-Flow ® Sampler surface expression method).

   The evaluation criteria will include the ability to localize and quantify natural gas leaks from SoCalGas facilities (accuracy and precision). The technology will be tested against leaks and controlled methane releases that fall within the distribution of leak sizes within SoCalGas' Distribution system.

2. Background/Approach

   SoCalGas is developing methodologies for improved quantification, geographic evaluation, and tracking of leaks from the gas systems. There are potential operational, environmental, and safety benefits for a reliable mobile quantification method of methane emissions flux rates. For example, the ability to quickly quantify methane flux rates would equip an operator to quantify volumes of methane emissions, potentially assign environmental risk-scores to pipeline segments and prioritize leak repairs, thereby reducing methane emissions.

   The purpose of this work is to explore a new mobile methane quantification capability for the [redacted] system.

   The test plan will be designed to first compare the technology with manufacturer specifications under Pico Study conditions. Depending upon the outcome, the technology will be rejected, or accepted and further field testing will ensue.

The laboratory evaluation will be carried out through BP 17 -AC 2. The field study evaluation will be supported by the Pico Study Area monthly survey, including controlled releases.

- Depending on the results of the field study, a cost-benefit evaluation of the pilot and field study will be included.

3. Accomplishments

The Field Study Area was identified, and monitoring surveys have been executed monthly.

Figure 2. Mobile Methane Mapping Vehicle

A Field Test Plan is complete (Q1 2020) and execution is planned for Q2 2020.

4. Next Steps

The monthly mobile surveys will continue as the basis for gathering data and improving the process. The Field evaluation is scheduled for the remainder of 2020.

5. Citations/References – *None at this time*

3.19. New Mobile Methane Quantification Technologies Research Projects (SCG-2017-010b) BP 20a AJ-1

Sponsor: SoCalGas/SDG&E
Status: Active

1. Objectives:

This project is to evaluate a mobile leak quantification technology and scientific methods that are more sophisticated and involves measuring more constituents in the atmosphere and more environmental variable. The [redacted] mobile based emission quantification technology was developed by Bubbleology Research International (BRI). The [redacted] is sensor based mobile lab. The objective is to determine if more sophisticated techniques could be used for mobile leak detection localization and quantification of system leaks along with speciation to differentiate the many varied sources of methane found within Southern California's urban environment.

2. Background/Approach

Most recent developments in mobile technologies for the natural gas Distribution industry have involved detection of methane and ethane at orders of magnitude lower detection levels (ppb verses ppm). Leak quantification estimates from such systems has been shown to be an order of magnitude when done correctly (+200%/-70%, see section 2.11). Prior work has also demonstrated that the vast majority of methane emissions within the Distribution operating environment is not from the natural gas pipeline system, driving a high false positive detection rate due to the inability of current systems to determine emissions source without the need for follow-up investigations of every detection. The purpose of this work is to explore the capability of the [redacted] mobile methane detection, localization, quantification and gas speciation technologies and methods.

The approach to meet the objective will include 2 test drives in the Pico Study area, consisting of a day drive and a night drive. The day drive will be executed over 3 consecutive days. The night-time testing will consist of 1 single night drive.

The results of these [redacted] test drives will be compared to other mobile based technologies per parallel projects under BP 20A-AJ1. The technologies will be tested against leaks and controlled methane releases that fall within the distribution of leak sizes within SoCalGas' Distribution system.

The specific results of this [redacted] project will be summarized in a table and compiled into a report with recommendations.

As possible, the test plan will include side-by-side comparison with technologies and practices currently used, so that the environment is not a factor in the comparison between the technologies for a given test set-up. Depending upon the outcome, the technology will be rejected or accepted, and further field testing will ensue.

3. Accomplishments

- Completed both day and night test drives with data for temperature, humidity, atmospheric pressure, methane, ethane, ozone, CO, ammonia, H2S, NOx, wind, boundary layer measurements, and GPS.
- Completed draft reports with analysis of day and night drives.

4. Next Steps

Continue evaluation of data and review of reports. GO/NO GO decision.

5. Citations/References

1. [redacted]

3.20. PE Leak Growth Rate from Slow Crack Growth Research Project (OTD 7.15.c) BP 20a AK-1

Sponsor: SoCalGas/SDG&E
Status: Active

1. Objectives

This is a basic Research and Development project that evaluates how leaks in polyethylene (PE) pipe that initiated due to slow crack growth evolve over time in terms of leak flow rate. This fundamental research will provide a better understanding of leak growth rates in vintage PE pipe materials and how this contributes to methane emissions. Phase 1 effort will focus on a first level understanding of how a crack grows in plastic material given different stress conditions and seasonal changes in a simulated buried operating environment.

2. Background/Approach

One of the main sources of leaks in vintage plastic pipe is from slow crack growth. Having a better understanding of how leak rates change as cracks evolve will provide valuable information that can be used to improve our understanding of emissions from (PE) pipelines. This project will add information regarding the axial growth of a through wall crack over time, thus completing the model for crack evolution over time. The approach to this project is as follows:

- Initiation of Slow Crack Growth (SCG) failures in polyethylene pipe and fitting assemblies.
  - Total of 18 specimens with leaks due to slow crack growth were prepared.
  - As soon as specimens exhibit through wall cracks, they are removed from test to be used in the following tasks.
- Development of an outdoor purpose-built leak flow rate test rig facility.
  - Designed and built a leak flow rate test rig facility.
  - The facility is housed with equipment and hardware to supply a continuous flow of air and to allow for continuous monitoring and acquisition of data.
  - Two stainless steel chambers were built, each one large enough to house up to nine (9) 4" pipe/fitting assemblies prepared previously. Each chamber was setup for continuous flow of air through nine individual specimens. The leak rate through each specimen was continuously monitored and recorded by means of an instrumented data acquisition system.
- Evaluation of the Leakage Characteristics of Aldyl-A Pipes (Long Term Testing)
  - The objective of this task is to evaluate the long-term leakage characteristics of the Aldyl-A pipe samples generated previously.

- Air will continuously flow through the specimens at two different set pressures. Samples tested in soil will have a 2-3 feet soil cover above them.
- The leak flow rate through each pipe specimen is continuously monitored and recorded by means of an instrumented data acquisition system for 10,000 hours duration.
- Leak rates through the soil are determined by switching the source gas from air to CNG on an individual specimen, applying pressure, and then using a high flow ® sampler to measure the leak rate at the soil surface and along each side of the (pipe) specimen.

3. Accomplishments

- [redacted]
- [redacted]
- [redacted]

4. Next Steps

Complete planned testing and perform failure analysis if any sample fails before the target 10,000 hours of testing.

5. Citations/References

1. *"Operations Technology Development NFP. (2018). Research Project Summaries"* https://www.otd-co.org/newsroom/Documents/OTD-Research-Project-Summaries-2018.pdf

3.21. Study Quality of Existing Pipe Fitting Inventory Research Project (NYSEARCH M2018-001) BP 22 AN-1

Sponsor: NYSEARCH
Status: Active

1. Objectives:

   This is a Basic Research & Development project to understand the influence that thread quality has on sealing performance by evaluating differences in pipe thread specifications and quality control requirements from National Pipe Taper (NPT) and Aeronautical pipe thread (ANPT), evaluating a sample of current operator materials, and perform preliminary tests to evaluate thread sealing characteristics.

   The objectives of the project are to:

   - Assess thread quality on commonly used NPT threaded components
   - Demonstrate the sealing performance of representative threaded connections with thread quality variation.
   - Determine the impacts of changing the thread specifications from National Pipe Taper (NPT) to Aeronautical NPT (ANPT)

   The result of this project will be a report which details the performance of improved thread quality for threaded fittings (NPT vs. ANPT), details the performance of thread sealants and assembly practices with respect to the leak resistance of the threaded joint and provides a recommendation to support changing material specifications or Company procedures.

2. Background/Approach

   Aboveground threaded components are a potential source for methane emissions. This project will provide a comprehensive analysis of methane emissions through commonly used threaded components in Meter Set Assemblies (MSAs) and Regulator Stations and identify potential opportunities for mitigation.

   This project includes three proposed tasks:

   Task 1) identify, based on data received from utility experts and advisory input from a statistician what fittings (size, type, vintages, etc.) to test cover range of inventories and to meet requirements for statistical significance.

Task 2) determine through sampling, gage measurement, and testing whether sampled fittings meet NPT spec and conform to ANPT spec,

Task 3) understand representative test conditions and, using a member-derived test plan and installation practices, test selected threaded connections under pressure for emissions/leak tightness.

3. Accomplishments

Performed random sample inspections of threaded fittings in multiple utility inventories to evaluate general industry conformance of manufacturers to NPT or ANPT specifications.

All tasks set in the proposed plan have been completed as of December 2019. Those tasks included:

- Inventory to select candidate fittings to test
- Measuring the fittings to determine NPT and possible ANPT dimensional compliance
- Develop and implement a test plan (Q3 2019) to evaluate sealing performance of a statistical sample of threaded connections with varying thread qualities. This involved assembly of NPT-NPT and ANPT-ANPT joints, pressurizing the joints according to a test matrix, and evaluating any leakage.
- Phase I report

The results from each task indicate additional testing is required to determine if and how ANPT dimensional compliance is a factor in whether a threaded connection leaks, and under what conditions.

Figure 1. Example of thread quality gages, threaded fittings, and thread sealing compound

4. Next Steps

The development of a statistical test plan to further examine threaded connections is expected to be complete 2nd quarter 2020. Upon completion the testing will be conducted.

5. Citations/References: *None at this time*

3.22. Methane Oxidation Catalyst Research Project (NYSEARCH M2017-004) BP 23 AP-1

Sponsor: NYSEARCH
Status: Active

1. Objectives:

   This is a basic research project to design and test novel catalytic materials for low-temperature methane oxidation as an alternative to flaring of pipeline gas. This will avoid the formation of NOx which occurs at elevated temperatures (>1000 deg C).

2. Background/Approach

   A proof of concept design and prototype methane oxidation unit is expected to be developed that improves the rate of methane combustion by a factor of ten (10x) higher than the commercial Palladium catalyst by attempting to optimize the amount of catalyst and processing time. 10x is the target, but a lower optimization may still be considered a success and support the effort to proceed. This requires research on the rate of catalytic oxidation at different temperatures, the amount of palladium and the concentration of methane.

3. Accomplishments

   A Palladium catalyst system that has a 10-fold increase in methane oxidation over the current commercial catalyst system for methane oxidation was developed, however it was agreed that the cobalt in the Pd catalyst system should be replaced by aluminum to reduce cost, which resulted in obtaining an 8-fold increase in methane oxidation over current commercial catalysts instead of 10. A Laboratory scale prototype of this champion Pd catalyst system was designed, built, and tested with natural gas at a flow rate of 200ml/min the laboratory which demonstrated the theoretical results were achieved.

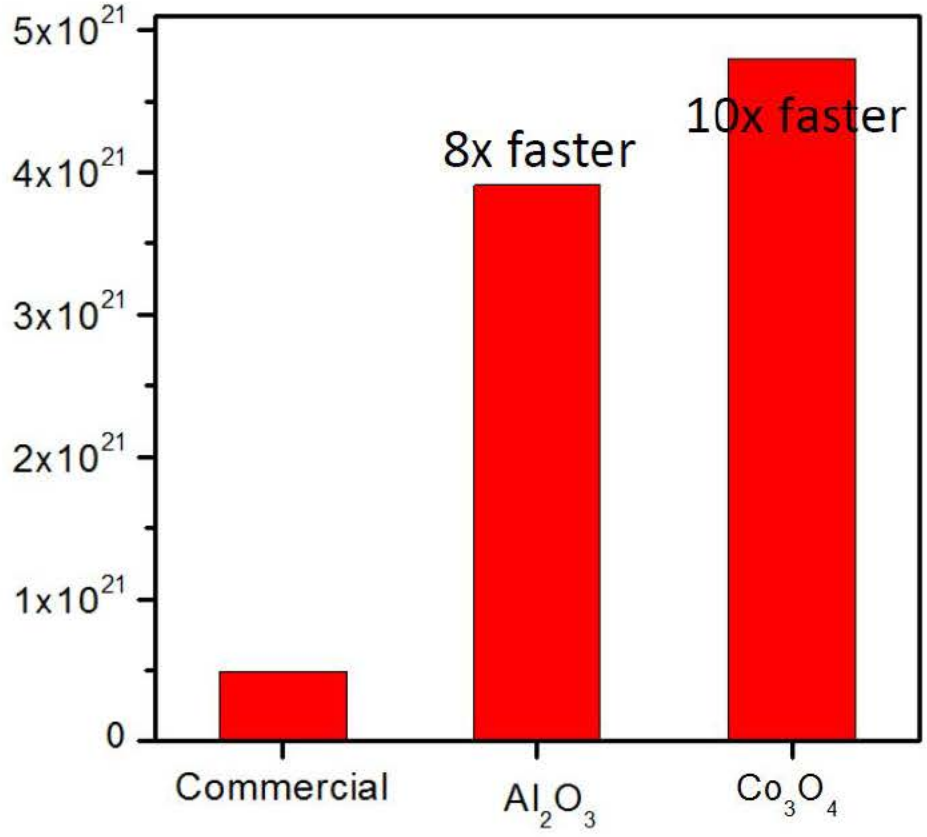


Figure 1. Pd/Al2O3 and Pd/Co3O4 prototypes have the best activity, and their reaction rate is 8 and10 times higher than the commercial sample.

4. Next Steps

- SoCalGas/SDG&E Go/NoGo decision based on evaluation of cost-effectiveness potential.
- NYSEARCH may continue with a follow-on phase with a commercial partner to determine if this system can be scalable to more practical flow rates suitable for field applications while still yielding the same results.
- A pre-commercial field deployable prototype may be developed and evaluated under field conditions to better evaluate the efficiencies the new system provides to the utilities in comparison to the commercially available systems.

5. Citations/References

1. https://questortech.com