October 2012

Pipeline Safety Information Grants to Communities - Technical Assistance Grants (TAG)
PHMSA Funding Opportunity Number DTPH56-10-SN-0002
U.S. Department of Transportation
Pipeline and Hazardous Materials Safety Administration
Federal Agency Contact: PHMSA
Office of Contracts and Procurement
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Title: Forest Vegetation as a Bioindicator to Detect Leaking Natural Gas Pipelines
Submitted by: The Pennsylvania State University, Penn State Institute for Energy and the Environment

Final Report:
Pursuant to contracted agreement between the US Department of Transportation, Pipeline Hazardous Materials Safety Administration (PHMSA) and The Pennsylvania State University and in compliance with Article III: Expected Program Outputs: The Pennsylvania State University submits this final report demonstrating completion of "**Forest Vegetation as a Bioindicator to Detect Leaking Natural Gas Pipelines"** (hereafter referred to as **"The Project"**).

Introduction:
The Project was base on the PHMSA credo, "An informed public plays a vital role in safety and reliability of pipeline operations." Under the direction of Principal Investigator (PI), Dr. Donald Davis, The Pennsylvania State University conducted a Technical Assistance Grant (TAG) predominantly to research how to detect leaks in natural gas pipelines using vegetation as bio-indicators. The referenced Penn State Research Team (Research Team) consisted of Dr. Davis and Ms Lynda Farrell, Blue Heron Consulting & HHF, LLC.

There are more than 2 million miles of distribution and transmission natural gas pipelines in the US, in both forested land and within or near municipalities. With the high number of pipelines transporting natural gas in the US, the potential for leaks in pipelines are inevitable, and will likely increase within the next few years as the Marcellus Shale play in the Northeast of the United States is exploited. Leaking pipelines cause ecological forest damage, lost revenue to the operators, and pose both health and safely risks to nearby municipalities. Leaks of natural gas are not easy to locate, especially when one considers the millions of miles of pipelines that currently exist. However, one way to locate leaking pipelines is by finding vegetation exhibiting damage characteristic of symptoms induced by leaking natural gas.

Utilizing 2009 PHMSA data for Pennsylvania (PA), Project research was based on 'Pennsylvania's 46,055 square mile landscape and 2009 existing infrastructure of 57,744 miles of gas pipelines. It was proposed that research be collected and reported at three levels: 1) literature review on the effects of natural gas on vegetation; 2) aerial surveys of selected natural gas pipelines using fixed-wing aircraft; and 3) follow-up field surveys if aerial surveys detected potential problem areas.

Literature Review:
Modern natural gas is mainly methane, which by itself is relatively harmless to vegetation. However, soil methanotrophic bacteria are stimulated by the methane in leaking natural gas, which they use as a carbon and energy source. As soil bacterial populations increase, they oxidize

more of the soil methane by utilizing the soil oxygen, (depleting soil oxygen levels) and releasing CO_2. Soil oxygen levels drop almost to zero, while CO_2 levels rise. Physical displacement of soil oxygen by the pressurized natural gas may also occur near leaks. Regardless, tree root death is due to lack of oxygen, mainly from methane oxidation by soil bacteria, which deplete soil oxygen to such low levels that the soil cannot support living plant roots.

In a classic, early paper (1967) in the journal "Gas Age", Mr. Stuart B. Enyon laid the basic groundwork for finding natural gas leaks using trees. His paper was entitled, "Current vegetation leakage survey techniques" and subtitled "Vegetation's sensitivity to natural gas can be a valuable aid in locating pipeline leakage." Mr. Enyon stated that the first systematic surveys in the United States to detect underground gas leaks, using visible symptoms on vegetation, were conducted in the late 1930s. Mr. Enyon related that, in the early days, experienced tree men and foresters were able to detect the symptoms of gas leakage on tree prior to detection by a layman. He further stated that the techniques improved over the years, so that by 1967, trees could be used to detect natural gas pipeline leaks "as a leakage-detection device," improving public relations and eliminating false claims for vegetation damage. Mr. Enyon's comments were mainly directed at gas damage to street trees, as opposed to forest trees, but are relevant to this proposal.

Mr. Enyon made several salient points regarding surveys to detect gas leaks by means of plant damage. Vegetation injury surveys with respect to leaks of natural gas should be conducted during the growing season, unless conifers are being surveyed. The amount of vegetation damage observed near a leaking natural gas pipe is directly related to the size of the leak. If the leaking pipe is at the soil surface, or elevated above ground, the pattern of vegetation damage may be quite variable as leaking gas is moved by the wind and cannot affect the roots. Visual symptoms on vegetation above leakage from a deeply buried pipe usually shows increasing gradations of damage intensity center of the area immediately above the leak to the perimeter of the affected area.

Natural gas from a leaking buried pipeline spreads upward and away from the leak in the form of an inverted cone. Vegetation damage at the surface is roughly circular in the horizontal plane. However, the extent and rate of spread of leaking gas is governed to a large degree by soil characteristics, especially soil texture. Sandy soils are very porous and offer little resistance to the spread of leaking natural gas. Vegetation above sandy soils may exhibit typical circular patterns of injury when viewed in the horizontal plane. In contrast, clay soils are quite dense and offer considerable resistance to gas spread. In heavy clay soils, natural gas will follow cracks or faults in the soil, and vegetation damage will be most severe immediately above the cracks, yielding a mosaic of damage patterns. High soil moisture content in the upper soils, such as may occur in the spring of the year, also may offer resistance to upward movement of leaking natural gas and affect the pattern of injured vegetation on the surface.

Excavation and backfill of the pipeline ditch results in major changes in soil compaction above the pipeline that greatly influences and facilitates the spread of leaking natural gas. The soil within the ditch is greatly disturbed, very porous, and less compacted than the soil on the sides of the ditch. Thus, gas leaking from the pipelines will spread much faster within and above the ditch than into the undisturbed soil on the sides of the ditch. The common pattern of vegetation damage above the leak in this case is not circular but rather linear.

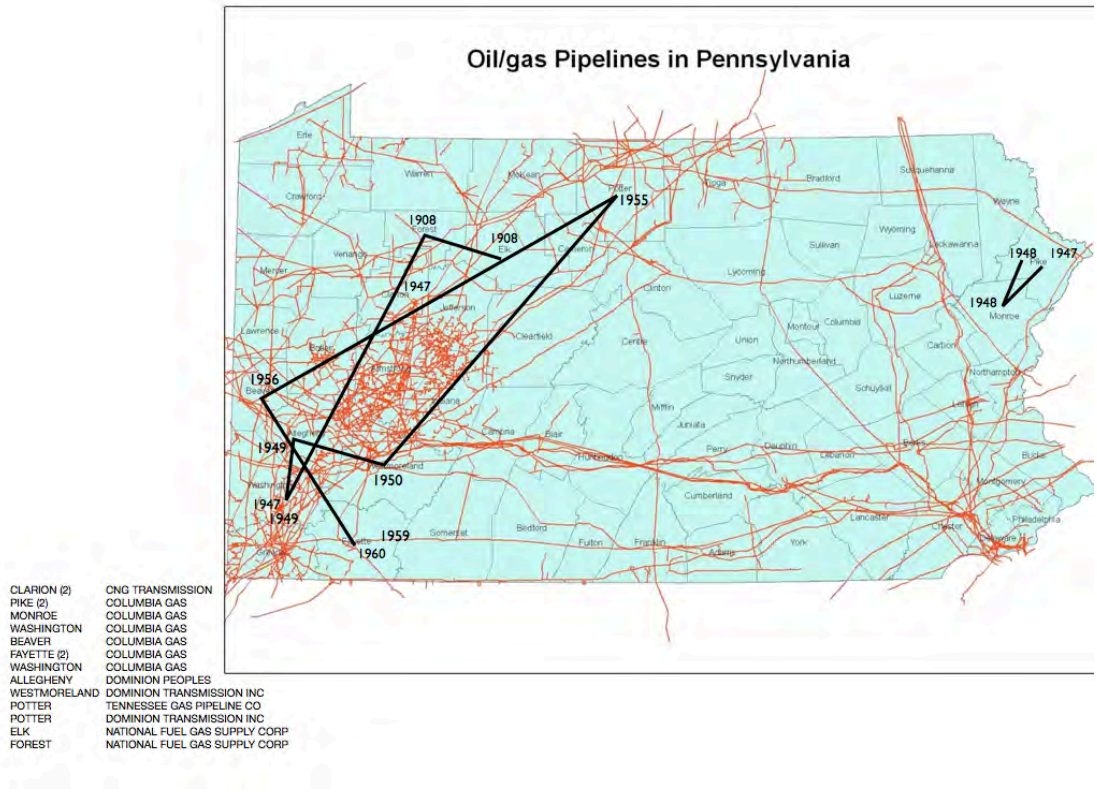
As early as 1958 one paper cautioned, "Symptoms induced by escaping … gas are easily confused with several other conditions…" including salt injury, drought, compacted soil, wilt diseases, root rots, insect problems, twig blights, cankers, and others. These cautions are still hold today. Part of this proposal involves taking samples from dead and dying vegetation (if found) along leaking pipelines, returning the samples to the proposed investigator's laboratory at Penn State, and examining the samples for gas damage, but also from common insect and disease problems not be related to natural gas from leaking pipelines.

The above literature review is applicable to development of outreach materials illustrating use of forest vegetation as bioindicators to detect gas leaks, available to pipeline operators, state agencies, municipalities, and the general public.

Aerial surveys of selected natural gas pipelines using fixed-wing aircraft

Mills Brothers Aviation, Burnt Cabins, PA, was selected to conduct aerial surveys to determine if we could detect leaking pipelines from the air, based on damaged/discolored vegetation in Pennsylvania. Mills Brothers routinely flies fixed-wing aircraft surveys for PA Department of Conservation and Natural Resources (PA DCNR), Bureau of Forestry, and is very familiar with the terrain and general environment of Pennsylvania.

Dr. Davis selected three pipelines for the survey, which totaled approximately 540 miles in length. One pipeline was in the extreme northern part of the state, mainly within forested areas; the west-to-east aerial pipeline survey at this location was approximately 90 miles in length, beginning near Bradford and ending near Wellsboro. Two parallel west-to-east pipelines were selected south of the first pipeline. The west-to-east survey of the first of the two pipelines, which encompassed approximately 220 miles, began near Cresson and ended near Pottstown. This survey area was located within a patchwork of forested and agricultural areas. The third survey, approximately 230 miles long and most southerly of the three, began at the top of Laurel Ridge in southwestern PA and proceeded easterly to south of Pottstown. This survey area encompassed a gradation from forested areas in the west to agricultural (2010) areas in the east.



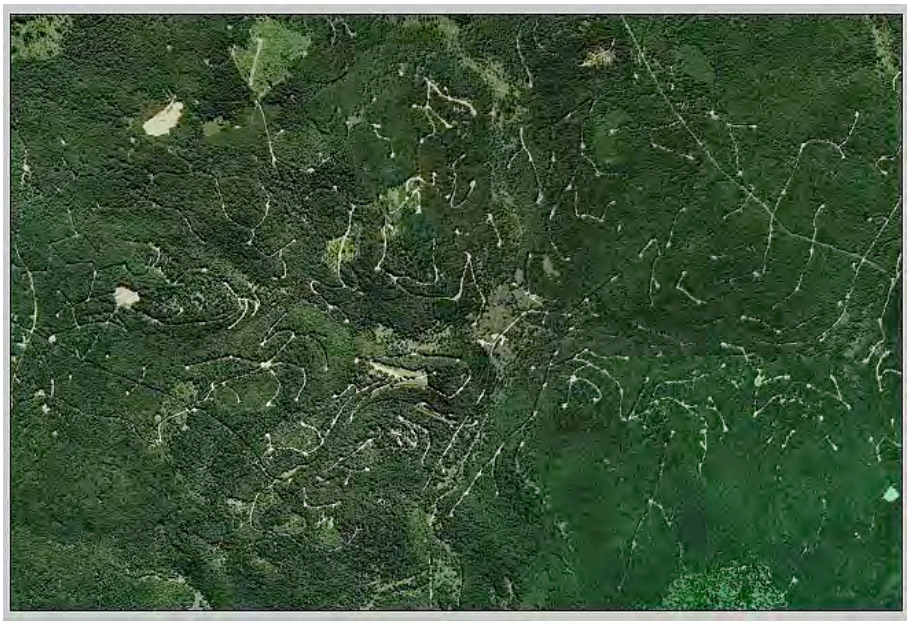
Mr. Mills and a photographer conducted the aerial survey on July10-11, 2011 using a fixed-wing aircraft. The overall objective of the survey to look for discolored (*e.g.,* brown) vegetation along the three pipelines, and if found, take aerial photographs and record GPS coordinates of suspicious areas. Suspicious areas were then to be investigated ("ground-truthed") by Dr. Davis to determine if the cause of the vegetative browning was due to a leaking pipeline, or due to other causes such as insect disorders or plant diseases.

It was anticipated that any brown areas that were observed from the air would be clearly distinguishable from surrounding normal, green, healthy vegetation. Unfortunately, two unforeseen events compromised this anticipation. First, there was a drought in July that resulted in brown vegetation along the pipelines within the survey routes, especially on the hotter west, or southwest-facing slopes. Secondly, there was a great deal of pipeline trenching, right-of-way widening and other related pipeline activities, which resulted in brown exposed soil, bull-dozed

trees and brush, etc. which masked potentially damaged vegetation from leaking pipelines. Thus, the emphasis of this report changed from forest vegetation to urban/suburban vegetation as biomonitors for detecting pipeline leaks.

The Marcellus Shale gas boom began in southwestern Pennsylvania in 2004, however, the full extent of impacts from drilling infrastructure throughout Pennsylvania were not anticipated by The Project. For example, the ecosystem of the Allegheny National State Forest (ANF), PA's only National Forest, was disrupted by the impact from the drilling infrastructure.

Allegheny National Forest:
August 11, 2007
Sackett area: Development roads fragmenting forest
(Photo: Allegheny Defense Project)



Allegheny National Forest:
2010
Gas Pipeline Infrastructure
(Stock Photo)

Located in the northwestern corner of the state, the ANF consists of 517,000 acres in Elk, Forest, McKean and Warren counties.

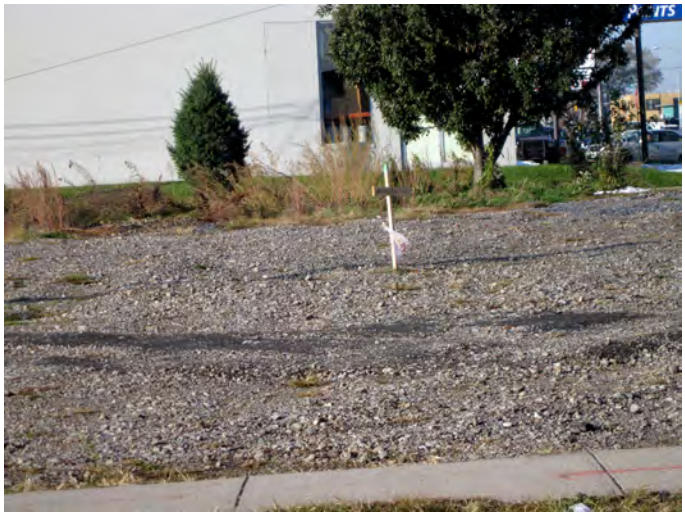
About 463,000 acres are forested, 42,000 acres are non-forest, and 11,000 acres are covered by water (primarily the Allegheny Reservoir).

As well as potential drilling from the Marcellus Shale play, numerous conventional gas/oil and unconventional gas wells are already located in the ANF.

Efforts to involve the gas pipeline industry in research of bio-identification of pipeline leaks, began in November 2010. Dr. Davis attended the Annual Pipeline Safety Trust Conference in New Orleans and spoke specifically with El Paso representatives who expressed interest "...in cooperative projects between Dr. Davis' Penn State Technical Assistance Grant (TAG through PHMSA) and the El Paso Pipeline Group..." since El Paso uses fixed-wing aircraft as well as

helicopters to survey pipelines and use pipeline vegetation as a bio-monitor to detect leaks from Texas to western Pennsylvania. Despite follow up efforts by The Project through January 2011, El Paso remained unresponsive to requests for partnering efforts.

Concurrently, in 2010 PHMSA reported a national annual record of 50 natural gas pipeline explosions and 17 deaths. Forty percent of these national deaths occurred in two southeastern Pennsylvania explosions. Then, on 10 February 2011, an aging Allentown gas line exploded leaving 5 dead and destroying 8 homes.



As The Project's statement of work included southeastern PA as a focal point, the Project requested PHMSA permission to refocus the main theme of The Project to approach bio-identification of natural gas leaks in urban settings, where bio-identification by grass and urban trees is both viable and could provide valuable data that could save lives. With the request approved, the Project turned attention to bio-identification within the urban setting of Allentown. Thus, education in bio-identification of gas leaks was extended from the public to urban governmental agencies, in conjunction with gas companies in the private sector, where it was deemed most needed in achieving higher levels of risk management.

Field Surveys: Allentown:

Dr. Davis was familiar with Picarro gas leak detection devices (Picarro Inc., Sunnyvale, CA). Dr. Davis and Ms Farrell approached Mr. Bob Ackley, who was working with Boston University's Picarro to obtain his expertise in gas leak detection. The Project goal for Allentown was to demonstrate and evaluate the use of Picarro in comparison to standard visual bio-identification of gas leaks by using city trees and other vegetation as bio-indicators of natural gas pipeline leaks in conjunction with the technology of the Picarro. The Picarro is capable of sensing and locating natural gas leaks in real-time while driving in an automobile equipped with a Picarro methane sensor. Could a confluence of citizen bio-identification of leak detection with the private sector use of Picarro, effectuate timely and accurate locations of Class One leaks and enhance risk management?

By May 2011, The Project deemed sufficient time had elapsed since the February 2011 Allentown explosion to begin outreach. Outreach began with Allentown Mayor Pawlowski by offering technical assistance in gas leak detection. The Project engaged:

Allentown:
- Mayor Ed Pawlowski
- Richard Young, Director of Public Works
- Rich Rasch, Utilities Engineer
- Mike Moore, Chief of Communications

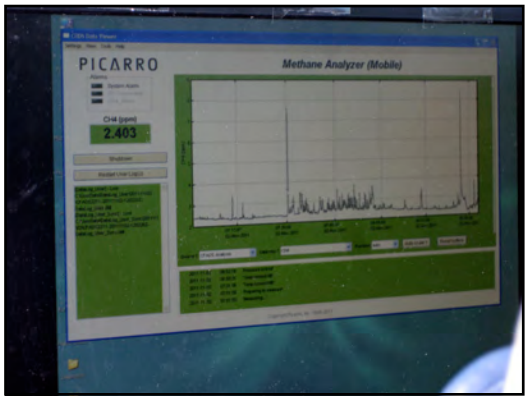
Additional outreach was made to:
- Dr. Nathan Phillips, Boston University
- Mr. Bob Ackley, Gas Safety Incorporated
- Mr. Paul Metro, Chief of Gas Safety, Pennsylvania Public Utilities Commission (PA PUC)

The cooperative effort scheduled three dates between July and October 2011,with final Project research occurring October 31 through November 4, 2011.

Mayor Pawlowski charged Richard Young and Richard Rasch with defining the geographic areas for demonstration and research. Richard Rasch became the team member for Allentown, defining research areas with hard copy maps of the city. Mr. Ackley took the helm of the Picarro

demonstration and Dr. Davis led visual bio-identification. Mrs. Farrell facilitated and documented The Project.

A vehicle equipped with the Picarro included two laptop monitoring capabilities: one screen



provided real time kml files depicting the onset of gas leak detection to the peak of concentration and corresponding waning of concentrations. The second monitor graphically illustrated peaks as well as methane concentrations (ppm).
As the Picarro was identifying potential leaks, Dr. Davis was conducting visual identification surveys typically used by utilities. Identification of dead and dying grass or trees observed by Dr. Davis correlated to the gps locations designated by the Picarro. The Picarro's identification of gas leaks, by nature, preceded the capacity of visual identification, however, the concurrence of visual and Picarro iidentification of gas leaks was verified.

A Picarro identification of a potential gas leak was ground tested first with visual bio-identification of dead and dying grass and trees as well as on the ground Gas Sentry readings.

Two reportable leaks occurred within 1,000 feet of each other and were called in to Allentown utility (UGI Utilities) to insure public safety. PHMSA and the PSU TAG research were identified to UGI during the calls. UGI responded immediately, classified these leaks as Priority 1 and repaired the distribution lines within the week.

The absence of readily detectable odorants in the call-in areas was noted by the Rearch Team, Bob Ackley, and Allentown's Rich Rasch. The Rearch Team determined due diligence dictated the need to verify requirements for odorization and contacted Mr. Paul Metro (Chief of Gas Safety, PA PUC) and Ms. Karen Gentile (PHMSA Community Assistance & Technical Services (CATS) Manager). The Research Team sought edification of requirements in odorization from both state and federal resources in order to document regulations in this report..

PHMSA's code on Odorization of gas, specific to distribution lines dictates distribution lines should be odorized; some transmission lines are odorized depending on whether they meet the following criteria:

§192.625 Odorization of gas.
(a) A combustible gas in a distribution line must contain a natural odorant or be odorized so that at a concentration in air of one-fifth of the lower explosive limit, the gas is readily detectable by a person with a normal sense of smell.
(b) After December 31, 1976, a combustible gas in a transmission line in a Class 3 or Class 4 location must comply with the requirements of paragraph (a) of this section unless:

(1) At least 50 percent of the length of the line downstream from that location is in a Class 1 or Class 2 location;
(2) The line transports gas to any of the following facilities which received gas without an odorant from that line before May 5, 1975:

(i) An underground storage field;
(ii) A gas processing plant;
(iii) A gas dehydration plant; or
(iv) An industrial plant using gas in a process where the presence of an odorant:

(A) Makes the end product unfit for the purpose for which it is intended;
(B) Reduces the activity of a catalyst; or
(C) Reduces the percentage completion of a chemical reaction

(3) In the case of a lateral line which transports gas to a distribution center, at least 50 percent of the length of that line is in a Class 1 or Class 2 location; or
(4) The combustible gas is hydrogen intended for use as a feedstock in a manufacturing process.

(c) In the concentrations in which it is used, the odorant in combustible gases must comply with the following:

(1) The odorant may not be deleterious to persons, materials, or pipe.
(2) The products of combustion from the odorant may not be toxic when breathed nor may they be corrosive or harmful to those materials to which the products of combustion will be exposed.

(d) The odorant may not be soluble in water to an extent greater than 2.5 parts to 100 parts by weight.
(e) Equipment for odorization must introduce the odorant without wide variations in the level of odorant.
(f) To assure the proper concentration of odorant in accordance with this section, each operator must conduct periodic sampling of combustible gases using an instrument capable of determining the percentage of gas in air at which the odor becomes readily detectable. Operators of master meter systems may comply with this requirement by-

(1) Receiving written verification from their gas source that the gas has the proper concentration of odorant; and
(2) Conducting periodic "sniff" tests at the extremities of the system to confirm that the gas contain odorant.

Efficacy of The Project was first noted when The Research Team was contacted by UGI two business days after call-ins. UGI Utilities Manager of Compliance & Damage Prevention, Eric Swartley, contacted Lynda Farrell through cell phone ID of the call-in to ask the purpose of the team's work. Ms Farrell outlined TAG work as: 1) research of use of bio-identification in conjunction with Picarro detection to minimize risks relating to safety issues in communities, 2) education of the public as an important tool in risk analyses 3) research of the use of bio-identification as a simple means for public participation and an efficient way to facilitate reporting of potential areas of leaking pipelines through the use of existing native bioindicator plants. Transparency in the dissemination of Project findings initiated a continuing dialouge with UGI.

UGI suggested a meeting with The Research Team to: 1) become informed and learn about the Allentown findings through the project; 2) develop an understanding of the Picarro technology; learn more of the process and procedures taken by The Project in leak detection and bio-identification concurrently applied and 3) to share UGI's approaches, qualifications, code requirements and their protocol in regard to public outreach, preparedness, and education.

The Research Team recommended it facilite such a meeting and to include the City of Allentown, PA PUC and Picarro by webcast. All parties in agreement, a meeting was scheduled and held on January 4, 2012 at UGI Reading Area Offices, 225 Morgantown Rd, Reading, PA. The Project

acted as liason to dissemination of findings, maintenance of transparency, and vetting of the technology behind the project's research. The meeting was attended by:

UGI Utilities, Inc:
Eric Swartley: Manager Compliance & Damage Prevention
Bob Krieger: South Region Ops VP
Jim Heintz: Manager Systems Integrity & Systems Operations

Research:
Dr. Donald Davis, The Pennsylvania State University, Department of Plant Pathology and Penn State Institutes of Energy and the Environment
Lynda Farrell, Blue Heron Consulting and Executive Director, Pipeline Safety Coalition
Bob Ackley, President, Gas Safety, Inc (via conference call)

Allentown:
Richard Rasch, Utility Engineer, City of Allentown

Picarro:
Michael Woelk, President & CEO Picarro, Inc. (via virtual connection)

PG&E: Pacific Gas and Electric Company:
Tim Clark, consultant (via virtual connection)

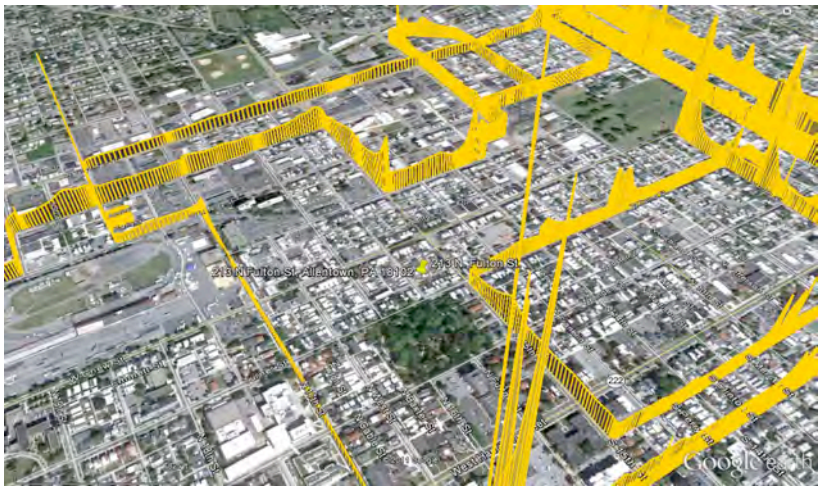
Invited/Unable to attend:
Paul Metro, Chief Gas Safety, PA PUC

A meeting inclusive of Allentown and UGI was a ground-breaking event between the utility charged with the safety of Allentown's distribution lines and the City, which was still reeling from the loss of life due to pipeline failure just one year prior. Virtual attendence of PG&E, the utility charged with the safety of San Bruno, CA, was included in this meeting for their efforts toward increasing leak detection capabilities and PG&E's ongoing vetting of Picarro. Initiation of efforts and transparency between UGI and PG&E was ground-breaking. The Penn State TAG was acknowledged as the driving force in achieving these precendents.

Virtual presentation of the Picarro Gas Leak Technology was followed by the Penn State/Gas Safety Incorporated's report of technique and findings, samples of Picarro kml[1] files, and Gas Safety Incorporated conclusions as had been provided to the City of Allentown. The Allentown report contains photographic documentation of the research process and is provided as the Attachment entitled, "Summary Report"

The January 4, 2012 meeting concluded with UGI reporting "cautious optimistism" in efforts to improve their leak detection protocol by further vetting the Picarro technology in conjunction with bio-identification and paticularly with winter patrols. Workproduct of this meeting presented itself in the issuance of an invitation to UGI, Allentown, and The Research Team to attend a January 2012, 3-day controlled field test at PG&E's Livermoore, CA leak-testing facility.

The next day, January 5, 2012, a gas pipeline explosion occured at 213 North Fulton Street, Allentown. The Project had not surveyed the 200 block, but did survey in close proximity. The Research Team provided the individual kml slide of the area of the explosion to both UGI and Allentown for reference.



A spokesman for UGI reported to the press the company's intent to replace all the gas lines under this block of Fulton Street "because they are old and made of cast iron".

[1] KML: a file format used to display geographic data in an Earth browser, such as Google Earth, Google Maps, and Google Maps

The spokesman would not say if that replacement had anything to do with the gas explosion that occurred just a few blocks away on 13th Street in Allentown on February 2011.

Five days later, on January 10, 2012, UGI informed the Research Team of their intent to join the PG&E Livermore, California 3-day controlled field test using the Picarro instument and other technologies, stating, "We (UGI) look forward to the evaluation and adaptation of the technology as it relates to gas distribution applications. The field test (scheduled) for (January) 18th and 19th appears to provide that opportunity."

Through work of the Penn State TAG, UGI also became aware of the Pennsylvania non profit, Pipeline Safety Coalition (PSC). Formed in January 2011, PSC's mission is: "To gather and serve as a clearinghouse for factual, unbiased information; to increase public awareness and participation through education; to build partnerships with residents, safety advocates, government and industry; and to improve pubic, personal and environmental safety in pipeline issues." The PSC Executive Director, Lynda Farrell, had developed a working relationship with PA PUC over time, as well as with Mayor Pawlowski during Congressional hearings regarding the Allentown explosion in which the Mayor and Ms Farrell had been called to testify. In Ms Farrell's capacity as Blue Heron Consulting and facilitator of the Penn State TAG, these relationships brought a level of trust to the collaborative effort and to the transparency offered by UGI in The Project.

UGI opined the importance of PSC, as a nonprofit dedicated to pipeline safety and unbiased source of education for the public and industry, being involved in vetting the Picarro. Ms Farrell's dual roles as TAG Project facilitator and Executive Director of PSC offered an opportunity to maximize outcomes of past and present work products, maximize efficient use of funding, and to facilitate foundational work of new relationships between utilities, cities, PHMSA, and educational based entities.

As introduction to the 3-day trial, UGI and The Research Team were provided background on process. Pipeline Research Council International (PRCI) had been leading a research and development program directed at automating monitoring and surveillance of gas and oil pipeline right of way (ROW) corridors. The program was referred to as the "Right of Way Automated Monitoring Program" (RAM) and was reported to have broad interest in the pipeline industry.

Cavity Ring-Down Spectroscopy (CRDS) had been identified as a technology that could potentially be applied to detect methane gas leaks from pipeline systems in automated monitoring and surveillance of pipeline ROWs. A field-test of the CRDS sensor for measuring and mapping natural and biogenic sources of methane gas concentrations was performed by NASA in June 2011, which confirmed sensor performance to a high degree of accuracy. Based on these findings, PRCI coordinated with PG&E to perform further testing of CRDS as a possible technology solution for gas leak detection, both ground-based as well as from aircraft patrolling pipeline ROWs. The parameters of research were consistent with those of to the Research Team.

Building on a field-testing program conducted by PG&E in September 2011 of controlled releases of compressed natural gas (CNG) at a number of locations along a ROW corridor, a CRDS sensor was placed in an airplane to evaluate if released gas could be detected using the CRDS sensor while flying along the pipeline ROW at elevations typically used by pipeline ROW patrol/ surveillance pilots. Additional testing was voluntarily performed by Picarro to assess how well the CRDS sensor performed in detecting and locating methane gas from a ground-based platform. This work consisted of placing the CRDS sensor in an automobile and driving along remote as well as congested urban/suburban locations of a controlled release route established for the field test. The results of these preliminary tests were encouraging.

A critical review of the test data indicated a need for further analysis to fully vet the performance capabilities of CRDS sensors as a technology solution for gas leak detection for the pipeline industry. Additional testing of Picarro's CRDS (and similar technology) was pursued by PRCI under the RAM Program to fully evaluate the potential application and deployment of commercial technology solutions for gas leak detection; from fixed wing aircraft and ground-based platforms. The additional testing was to be performed in January 2012 during the 3-day controlled field-test at PG&E's Livermoore, CA leak-testing facility.

"Field Testing of Gas Leak Detection and Locating Technology" was held at PG&E's 45-acre Livermore testing and training facility January 18-19, 2012 at Livermore, CA. The testing facility encompasses 33 test transmission and distribution lines and mock dwellings in a small town setting. The coordinated field testing of gas leak detection and locating technology trial was co-sponsored by PG&E and the PRCI Right of Way Automated Monitoring (RAM) Program.

Attending the 3-day controlled field test were pipeline operators and other interested stakeholders including, but not limited to: Enbridge, GT&E, AGA, PGE, Spear Group, Marathon Pipeline, El Paso, TransCanada, Buckeye, NiSource, Sempra Utilities, Exxon, Spectra, Common Ground Alliance, UGI, Pipeline Safety Coalition and the Penn State University TAG project.

The field-test addressed: 1) evaluating Cavity Ring-Down Spectroscopy (CRDS) sensors for detecting and locating gas leaks for both transmission and distribution pipeline systems, 2) the application of CRDS sensing technology from airplanes for routine leak patrol of transmission pipelines and from ground-based platforms (cars, trucks, ATVs, etc.) for monitoring in more congested locations where airborne sensing might not be a viable approach, 3) evaluating ground-based sensing for application to monitoring of gas distribution systems and 4) CRDS technology as a potential low-cost, low maintenance solution for pipeline ROW leak detection monitoring as part of an integrated technology solution for automating pipeline ROW monitoring and surveillance and 5) determining capability needs from industry.

PRCI presented results of prior testing using CRDS in aircraft and discussed how that data would be applied to developing an integrated technology solution for gas leak detection for transmission pipeline ROW monitoring. Other entities providing supporting research and expertise were University of California at Davis, Scientific Aviation, Picarro, Inc and PG&E's Applied Technology Services Department.

Field-testing consisted of two major activities. First, ground-based sensing applications included a series of controlled gas releases at the Livermore facility. Releases were measured as methane concentrations by CRDS, which was housed within car that drove through the facility and drove past leak locations. The data obtained was gathered to be used for developing algorithms for optimizing sensor performance under a range of wind, temperature, and other atmospheric conditions, as well as to predict methane gas plume behavior when released from a gas transmission and distribution pipeline system and for confirming the sensitivity of CRDS sensing for gas leak detection. The ground-based releases were also used to test CRDS sensors that measure carbon isotope ratios capable of distinguishing methane sources (*i.e.,* pipeline *vs.* other biogenic or anthropogenic sources).

Releases were performed over the 3-day period to provide a range of weather test conditions to ensure the systems developed using CRDS were based on a comprehensive set of measurement data.

Secondly, outcomes of field-testing were intended to integrate the derived models and algorithms from the field tests into a prototype interface system for the CRDS sensor, which was tailored for aerial and ground-based platforms. Optimally, the prototype interface system should consist of a hardware and software tool collaboratively developed by PRCI, Picarro, UC Davis, Scientific Aviation (SA), and other potential project participants. Conceptually, the interface system would create a gas leak detection probability window by analyzing key physical variables (wind speed, wind direction, air temperature, altitude, topography, map information, etc.) in real time; the prototype system to be designed to automatically perform data processing, mapping, calculations, presentation, display, and reporting functions for pilots and/or drivers in real time, as a tool to help crews identify and locate leaks in natural gas pipelines within an identified reasonable range of accuracy. The interface system and integrated software would be fully self-contained, portable, and able to be installed on fixed wing aircraft, within a ground-based vehicle, and ultimately in a backpack for areas only accessible by foot.

Field-testing was expected to generate data needed to enable development of engineered technology incorporating CRDS technology for ground-based and aerial leak detection of both natural gas distribution systems and transmission pipelines that would be low maintenance, easy to operate, and that would allow for detection of methane gas at low concentrations, differentiate sources of methane (pipeline origin *vs.* other sources), and require little to no calibration or maintenance. A final report of findings was not accessible at time of this report writing.

As result of The Project's Pennsylvania meetings with UGI, Allentown and Picarro and the Livermore field trials, Robert Krieger, UGI Utilities, Southern Regional Vice President, announced a February 29, 2012 review and field demonstration of "*a new natural gas leak detection technology...being developed by Picarro, Inc., a Santa Clara, CA-based company, (which) has been developing its gas analyzer in collaboration with the U.S. pipeline industry. The unit that will be reviewed on February 29 is currently being adapted to natural gas distribution pipeline survey applications. Picarro is partnering with Pipeline Research Council International (PRCI) in collaboration with PG&E in California to develop the technology's application to the natural gas distribution sector.*

UGI Utilities has had the opportunity to observe the Picarro technology in the field, and believes it would be useful to conduct a field test of the technology within the UGI service territory. UGI also believes it would be useful for industry and regulatory stakeholders to review the demonstration of this technology."

The February 29 review of the Picarro gas analyzer took place at the Lower Swatara Social Hall in Middletown, PA. UGI representatives were joined by representatives from state regulatory agencies and natural gas industry representatives for a field demonstration in the community of Middletown, PA.

UGI Utility hosts:
- Eric Swartley, UGI Utilities, Inc, Manager Compliance & Damage Prevention
- Bob Krieger, UGI Utilities, Inc, South Region Ops VP
- Jim Heintz, UGI Utilities, Inc, Manager Systems Integrity & Systems Operations
- Timothy Rhodes, UGI Utilities, Inc, PA Manager Operations

PA PUC:
- Wayne E. Gardner, Commissioner
- Paul Metro, Chief Gas Safety
- Andrew Geibel, Gas Safety Inspector
- Jan Freeman, Executive Director

Picarro, Inc:
- Michael Woelk, President & CEO Picarro, Inc.
- Eric Crosson - Chief Technology Officer
- Tim Clark, PG&E consultant

Pipeline Research Council International, Inc. (PRCI):
- Mark Piazza, Program Manager

Utilities:

Fred L. Bradley, Baltimore Gas & Electric, Project Manager
Jack Mackin, Director, Operations, Greater Pittsburgh Area, Equitable Gas
Dave Luby, Exelon Corporation
Kirin Kothari, Gas Techology Institute
Ray Geesey, Compliance Specialist, Columbia Gas of PA/NiSource Company
Ed Urban, Mechanical Engineer, Consultant, New Jersey Natural Gas
Daphne D'Zurko, Executive Director, Northeast Gas Association
Eric Gerstel, Director Gas Operations, Yankee Gas Services Co.
John Frick, Public Service Electric and Gas Company, Senior Distribution Supervisor
Kevin Powers, Public Service Electric & Gas Co, Manager: Process/Operations/Resources/Delivery
Doug Staebler, North Virgina Utilities, VP Engineering/Real Estate
David M Huey, Washington Gas
M.S. Nead, Washington Gas
Theodore Schrimisher, Washington Gas
Charles Dippo, SJI (South Jersey Industries)
Catherine Duncan, SJI (South Jersey Industries)
Lisa Vallaster, SJI (South Jersey Industries)

Research Team:
Lynda Farrell, Executive Director, Pipeline Safety Coalition & Blue Heron Consulting

UGI representatives provided an overview of the Picarro technology, incorporated a status report of UGI's vetting of the technology and its potential use in the Northeast. The meeting encouraged probative interaction both before and after a Picarro driving demonstration that used blind control gas releases. UGI's intention of initiating further vetting of gas leak technologies with attendees of this meeting was achieved.

In June 2012, The Allentown Morning Call reported findings of a 16-month investigation conducted by the Pennsylvania Public Utility Commission (PUC) and in cooperation with UGI Utilities, whose gas lines erupted February 9, 2011. PUC said UGI had been too "passive" in replacing aging infrastructure, cited multiple safety violations, recommended a series of corrective actions and the imposition of a $386,000 fine on the utility; the maximum allowed by law. The cause of the explosion was determined to be a leak emanating from a crack in an 83-year-old cast iron gas distribution line. The formation of the crack was accelerated by corrosion in areas where the pipe was supported by wooden blocks. Also cited was improper (low) levels of odorant, as had been observed and reported to PA PUC by The Project in October 2011.

The findings reignited interest from both UGI and PUC in The Project's focus on gas leak detection technologies. The Project and Pipeline Safety Coalition were sought to facilitate two meetings to educate public officials, regulators and local utilities.

The first of these two meeting was held in Allentown, July 12, 2012 and was based on The Project's demonstration of risk management technology and updates in the Picarro technology as pertained to urban settings. The meeting again brought the City and utility UGI together in accessing implementation of Picarro gas leak technology in conjunction with bioidentification of gas leaks in Allentown and the UGI service area. Senator Robert Casey had expressed interest in reducing pipeline risk in Allentown during several meetings with Mayor Pawlowski and was invited to attend this demonstration. Perhaps of more substance was the participation of the Pennsylvania Public Utilities Commission (PAPUC).

The meeting was an on-ground, hands-on demonstration and drive through the city of Allentown, with each attendee afforded the opportunity to ride in a car equipped with the Picarro gas leak detector. Attendees included:

Pennsylvania Public Utilities Commission:
Paul Metro, Chief of Gas Safety

Senator Robert P. Casey, Jr. represented by:
Carol Obando-Derstine, Regional Manager for Berks, Carbon, Lehigh and Northampton Counties

Allentown:
Richard Rasch, Associate Utility Engineer, Department of Public Works

Research Team:
Dr. Donald D. Davis, TAG PI and Professor, The Pennsylvania State University, Department of Plant Pathology and Penn State Institutes of Energy and the Environment
Lynda K. Farrell, Executive Director, Pipeline Safety Coalition & Consultant, Blue Heron Consulting

Picarro:
Eric Crosson, Chief Technology Officer
Tim Clark, Vice President Business Development - Energy
Chris Vale, Engineer
UGI Utilities:
Eric Swartley, Manager Compliance & Damage Prevention
Tim Rhodes, PA Manager Operations
Dan Fitzgerald & Associates, Inc:
Dan Fitzgerald, President, Safe Gas Survey Company (California)

A meeting on the following day, July 13, 2012, at UGI's Middletown, Pennsylvania location, gathered members of PAPUC for a state agency evaluation of the Picarro; a technology brought to Pennsylvania and to PAPUC as a direct work product of The Project's demonstration of risk management technology. Vetting from October 2011 to June 2012 of CRDS sensing for gas leak detection through use of Picarro in conjunction with bioidentification provided data of significant import for a considered review by PAPUC.

A chronology of UGI's vetting process was combined with yet another update from Picarro verifying the capability to distinguish carbon isotope ratios thereby identifying a methane source as pipeline *vs*. other biogenic or anthropogenic sources. During the meeting, attendees were also made aware of the 2012 Small Business of the Year Award to Picarro by the US Department of Energy. A critical audience asked probative questions and drove in a car that was equipped with the latest Picarro technology. Before adjourning, consensus observation was potential for "game changing" capabilities in gas leak detection. PAPUC expressed interest in obtaining a Picarro device and UGI reiterated their interest. Attendance was intended for profession review and included:

Pennsylvania Public Utilities Commission:
Commissioner Wayne E. Gardner
Paul Metro, Chief of Gas Safety
PA PUC Staff
UGI Utilities:
Eric Swartley, Manager Compliance & Damage Prevention
Bob Krieger, South Region Ops VP
Jim Heintz, Manager Systems Integrity & Systems Operations
Tim Rhodes, PA Manager Operations
Picarro:
Eric Crosson - Chief Technology Officer
Tim Clark, Vice President Business Development - Energy
Chris Vale, Engineer
Research Team:
Lynda K. Farrell, Executive Director, Pipeline Safety Coalition & Consultant, Blue Heron Consulting
Dan Fitzgerald & Associates, Inc.
Dan Fitzgerald, President, Safe Gas Survey Company

Proactive participation by PAPUC has led UGI to an exploration of gas leak detection protocol incorporating the use of bio-identification and Picarro, particularly in winter patrol surveys.

Summary

The extremely rapid development of extraction (drilling) and distribution (pipelines) of natural gas within the Marcellus Shale region of Pennsylvania, coupled with the tragic February 2011 Allentown pipeline explosion, prompted refocusing of the TAG objectives as originally proposed by The Project. Redirecting efforts toward bio-identification (vegetation damage) of pipeline gas leaks within an urban area such as Allentown, in conjunction with use of new and improved gas leak detection technology, a promising future in advancing pipeline gas leaks was advanced within this TAG effort.

Education in bio-identification of gas leaks was also re-focused from the public to education of industry and city/state/federal government agencies and the private sector, where it was deemed essential to achieve greater levels of positive risk management. Educational outreach started with UGI Utilities, extended to Federal Congressman Casey and the City of Allentown, with outreach

beyond Pennsylvania initiated during The Project by UGI Utilities. All of these positive efforts were a direct result of this TAG.

Outcomes of this TAG allowed us to refine survey techniques designed to detect leaking natural gas using vegetation as bioindicators in urban settings, in conjunction with modern state-of-the-art methane-based gas leak detectors. The Project initiated vetting of the most current CRDS sensing for gas leaks by the City of Allentown, as well as UGI (the utility serving Allentown), and the State Public Utility Commission. Because of the difficulty of using bio-identification during winter months when much vegetation was not available, or may not be highly-responsive to gas. The Project introduced the Picarro CRDS as a time-efficient, technologically sound approach that could be used to increase the frequency of winter patrols.

The positive results of this TAG Project can extend far beyond the limited areas surveyed in Pennsylvania. These initial findings will be extended and built upon by Pipeline Safety Coalition in providing unbiased, continuing facilitation of improved working relationships between other cities in Pennsylvania, as well as cities in other states, and utilities that provide their natural gas. Results of this TAG grant also demonstrated the value of risk management that utilizes bi-identification (vegetation damage from natural gas) in conjunction with state-of-the-art instruments such as the Picarro, when dealing with natural gas pipeline leaks.

Summary Report:

December 30, 2011
The Pennsylvania State University, US DOT PHMSA Technical Assistant Grant Project

The City of Allentown: Bio-identification and Piccaro Leak Detection

Research Team:
Dr. Don Davis, Penn State University, State College, PA
Bob Ackley, President, Gas Safety Incorporated, Southborough, MA
Lynda Farrell, Executive Director, Pipeline Safety Coalition, Downingtown, PA

Allentown Team:
Mayor Ed Pawlowski, Allentown, PA
Richard Rasch, Utility Engineer, City of Allentown, PA
Richard Young, Director of Public Works, City of Allentown, PA
Mike Moore, Communications, City of Allentown, PA
Diane Miller, Office of the Mayor, Allentown, PA

Summary Report:
Penn State University, US DOT PHMSA Technical Assistance Grant (TAG), *"Forest Vegetation as a Bioindicator to Detect Leaking Natural Gas Pipelines,"* Allentown Natural Gas Safety Assessment:
November 2, 2011 - November 3, 2011

Dr. Davis and contractor Lynda Farrell contacted Allentown Mayor Pawlowski's office in March 2011 offering technical assistance in gas leak detection through a Penn State University awarded PHMSA TAG. The project sought to use city trees and other vegetation, if available at time of survey, as bioindicators of natural gas pipeline leaks. The project engaged Bob Ackley, Gas Safety Incorporated, for his expertise in leak detection in Boston, MA by bioidentification aided by the methane-detection technology of Picarro.

On November 2, 2011 and November 3, 2011 Allentown Utility Engineer, Richard Rasch accompanied Bob Ackley, Dr. Don Davis and Lynda Farrell on a 2-day demonstration of the Picarro Gas Leak Detection device coupled with visual bio-identification methodology. Bob Ackley's report of technique and findings is provided (pages 5 - 8) as **Attachment A**.

Two call-ins were made to UGI based on visual findings of dead and dying grass and trees coupled with high readings from the Picarro, as well as on the ground Gas Sentry readings. Call-in locations were #2239 South 12th Street and #2159 South 12th Street. Calls were made to insure public safety, and PHMSA TAG work was identified to UGI.

UGI responded to call-ins immediately and per update from Rich Rasch finished temporary patches for two street cuts at the #2239 location and one street cut at #2159. A third location was also repaired north of the railroad crossing by the GE Plant. The Research Team had noted a potential for a leak but as UGI responded immediately, ground verification was not performed by the team. The specific repair work done in this area is unknown to the Research Team.

The absence of readily detectable odorants in the South 12th Street call-in areas was noted. As followup to questions regarding odorants, Paul Metro, Chief of Gas Safety, PA PUC informed the research team of the regulatory process, siting odorant detection to be federally regulated and leak detection regulated by the utility. Karen Gentile, Community Assistance & Technical Services (CATS) Manager, U.S. Department of Transportation Pipeline & Hazardous Materials Safety Administration (PHMSA) e-mail: Karen.Gentile@dot.gov Tel: 609-989-2252, Cell: 609-433-6650 was also contacted and provided PHMSA's code on Odorization of gas, noting all distribution lines should be odorized; some transmission lines are odorized depending on whether they meet the criteria identified below:

> §192.625 Odorization of gas.
> (a) A combustible gas in a distribution line must contain a natural odorant or be odorized so that at a concentration in air of one-fifth of the lower explosive limit, the gas is readily detectable by a person with a normal sense of smell.
> (b) After December 31, 1976, a combustible gas in a transmission line in a Class 3 or Class 4 location must comply with the requirements of paragraph (a) of this section unless:
>
> (1) At least 50 percent of the length of the line downstream from that location is in a Class 1 or Class 2 location;
> (2) The line transports gas to any of the following facilities which received gas without an odorant from that line before May 5, 1975:
>
> (i) An underground storage field;
> (ii) A gas processing plant;
> (iii) A gas dehydration plant; or
> (iv) An industrial plant using gas in a process where the presence of an odorant:
>
> (A) Makes the end product unfit for the purpose for which it is intended;
> (B) Reduces the activity of a catalyst; or
> (C) Reduces the percentage completion of a chemical reaction
>
> (3) In the case of a lateral line which transports gas to a distribution center, at least 50 percent of the length of that line is in a Class 1 or Class 2 location.; or
> (4) The combustible gas is hydrogen intended for use as a feedstock in a manufacturing process.
>
> (c) In the concentrations in which it is used, the odorant in combustible gases must comply with the following:
>
> (1) The odorant may not be deleterious to persons, materials, or pipe.
> (2) The products of combustion from the odorant may not be toxic when breathed nor may they be corrosive or harmful to those materials to which the products of combustion will be exposed.
>
> (d) The odorant may not be soluble in water to an extent greater than 2.5 parts to 100 parts by weight.
> (e) Equipment for odorization must introduce the odorant without wide variations in the level of odorant.
> (f) To assure the proper concentration of odorant in accordance with this section, each operator must conduct periodic sampling of combustible gases using an instrument capable of determining the percentage of gas in air at which the odor becomes readily detectable. Operators of master meter systems may comply with this requirement by-

(1) Receiving written verification from their gas source that the gas has the proper concentration of odorant; and
Conducting periodic "sniff" tests at the extremities of the system to confirm that the gas contains odorant.

We trust this information will be helpful to Allentown in addressing what the teams queried might be inadequate levels of odorant.

On November 8, 2010, Eric Swartley, Manager Compliance & Damage Prevention, UGI Utilities, Inc, Cell: (610) 842-8357, Email: eswartley@ugi.com, contacted Lynda Farrell to ask the purpose of the team's work. Lynda outlined the TAG work, bio-identification methods, and Picarro technology.

Both the Research Team and Allentown Team have been engaged in continuing dialogue. A meeting has been scheduled with UGI, members of the Research and Allentown Teams, Michael Woelk, President & CEO, Picarro, Inc. and Bob Ackley, Gas Safety, Inc. Details follow:

Date: January 4, 2012
Time: 9AM
Location: UGI Reading Area, 225 Morgantown Rd, Reading
Contact: Eric Swartley: **Cell:** 610-842-8357
Attending:
Eric Swartley, Manager Compliance & Damage Prevention, UGI Utilities, Inc
Bob Krieger, South Region Ops VP, UGI Utilities, Inc: responsible for Field Ops and Engineering
in UGI's service territory which includes the Lehigh Valley
Jim Heintz, Manager Systems Integrity & Systems Operations, UGI Utilities, Inc: responsible for
system surveillance programs which include leak survey
Dr. Donald Davis, The Pennsylvania State University, Department of Plant Pathology and
Penn State Institutes of Energy and the Environment
Lynda Farrell, Executive Director, Pipeline Safety Coalition
Richard Rasch, Utility Engineer, City of Allentown
Attending:
Virtual Connection: Michael Woelk, President & CEO Picarro, Inc.
Conference Call: Bob Ackley, President, Gas Safety Inc,
Purpose:
UGI has asked to meet to develop an understanding of:
1) Picarro technology and Allentown findings to date
2) bio-identification approach to leak detection and the process and procedures applied in evaluations of the surveys completed in Allentown

UGI will share their approaches, qualifications, code requirements and what they do in regard to outreach with public awareness: education, awareness and preparedness.

Michael Woelk will discuss the most current Picarro technology and applications.
Review of the November 2011 Allentown Survey performed by Dr. Davis, Bob Ackley, Lynda Farrell and Richard Rasch.

For your convenience, photographic documentation of the research process and sample of Picarro kml files are attached as a pdf file, Pages 9-28. KML is a file format used to display geographic data in an Earth browser, such as Google Earth, Google Maps, and Google Maps for mobile.

Dr. Davis and the team thank the Mayor and his team for participating in this research project. We welcome the opportunity to work with Allentown in the future to promote natural gas safety in your community.

Best Regards,

US DOT PHMSA TAG Research Team:
Lynda Farrell
Executive Director
Pipeline Safety Coalition
www.pscoalition.org
Phone 610.269.4977
Cell: 484.340.0648
Email @ lkfarrell@verizon.net

Dr. Donald Davis, Professor
The Pennsylvania State University
Department of Plant Pathology and
Penn State Institutes of Energy and the Environment
323 Buckhout Laboratory
University Park, PA, USA 16802
email: ddd2@psu.edu

Gas Safety Incorporated

Allentown Natural Gas Safety Assessment

Bob Ackley

11/9/2011

Gas Safety Incorporated
16 Brook Lane
Southborough, Massachusetts 01772
774-922-4626
www.gassafetyusa.com

November 9, 2011
Dr. Donald D. Davis, Professor
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Department of Plant Pathology
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Blue Heron Consulting & Honeysuckle Hill Farms, LLC
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Email @ lkfarrell@verizon.net

Richard Rasch
Department of Public Works - Engineering
641 S. 10th St., 3rd Floor
Allentown PA 18103
phone: 610.437.7584
fax: 610.437.7614

RE: Natural Gas Safety Assessment November 2&3 2011

Gas Safety Inc. on November 2, 2011 and November 3, 2011 conducted safety audit leak surveys in Allentown Pa of areas selected by the Department of Public works engineering department as well as random areas in the vicinity of Allentown, PA. The areas selected were surveyed with a Picarro Cavity Ringdown Spectrometer that calculates methane readings in the parts per million quantities and plots those readings via GPS longitude and latitude coordinates on Google Earth KML files.

General Assessment of Picarro Survey Results

The Allentown gas distribution system has had extensive recent repair work as evidenced by many repair patches throughout the city. There were no large volume leaks detected by the Picarro equipment but many typical smaller leaks that are common on cast iron gas distribution systems. Allentown has roughly 400 miles of roadway throughout the city limits and typical gas distribution leak rates fall into the 1-4 leaks per mile range. From the survey audit results, there is an appearance that Allentown would fall on the lower end of the typical leak rates seen on similar gas distribution systems. Allentown Google Earth KML files for this survey are attached to this report.

DPW Selected areas:

1. Union Boulevard & North Van Buren Street. Installed 1923, 12” cast iron main.

A slight read was indicated on North Van Buren Street north of Union Boulevard. There were no detectable levels of gas near any curb or manholes.

2. Club Ave & East Tremont Street. 1923 4" unknown pipeline
   A slight read was indicated on Club Ave south of East Tremont Street. There were no detectable levels of gas near any curb or manholes

3. North 12th Street & West Liberty Street
   No readings detected

4. North 17th & West Allen Street
   No readings detected

5. South 23rd Street & Walnut Street
   A slight read was indicated in the intersection of South 23rd Street & Walnut Street. There were no detectable levels of gas near any curb or manholes.

The Picarro unit records methane concentrations at one second intervals and plots those readings via corresponding GPS coordinates. A continuous map of methane readings is displayed showing background levels (a small amount of methane is present at all times) and spikes from unknown sources, but most likely, from the gas distribution system. Attached are four sample field drawings of existing leaks on the system detected in Allentown.
Additional Leaks (Reports Attached)

1. 2435 Walnut Street – Grade 2
2. 1644 Walnut Street – Grade 2
3. 2239 South 12th Street – Grade 2
4. 2159 South 12th Street – Grade 2

Recommendations

1. Public service announcements for Pennsylvania One Call System should be aired on the importance of marking underground utilities prior to any excavations. Information should also be made available for any entity applying for a street opening permit or building permit application.

2. Smell Something – Say Something / See Something – Say Something campaign. This is a campaign developed by Gas Safety Inc. to promote public awareness of gas odors and public awareness of dying vegetation as an indicator of leaking natural gas. This program urges anyone who smells gas to call 911. Public service announcements as well as "Scratch and Sniff" cards can be mailed to every household in the community and/or distributed at public schools. It is noted here that mercaptan (odorant) levels appeared very faint at all leaks detected. A test of mercaptan levels should be conducted as soon as possible to insure proper detection of leaks by the general public.

3. Aggressive cast iron replacement program that focuses on smaller diameter cast iron pipelines that are prone to crack.

4. Aggressive bare steel main and service replacement program.

5. Cast Iron "Winter Patrol Survey" should be required as soon as frost conditions are present. A continuous monitoring of cast iron mains on a daily basis will greatly reduce the chance of a tragic incident. Allentown has a tremendous amount of cast iron

pipelines as well as "Wall to Wall" paved areas that are very hazardous when frost conditions are present. Leaks under frost conditions can easily migrate to buildings causing hazardous conditions.

Conclusion

The Allentown gas distribution system is typical of other urban distribution systems of similar age. The ever present danger of damage caused by third parties needs continual promotion from all available resources in the effort to protect life and property. Mechanical failures and corrosion are equally important in the effort to protect life and property. Natural Gas operators "Roll the Dice" with so much deadly cast iron and bare steel pipelines in the ground, are actively replacing mains and services to prevent incidents from occurring. The problem is how we best protect the public while the system is gradually replaced. Conducting winter patrol surveys when frost conditions are present will greatly reduce the risk of danger from cracking mains. Odorant levels must be maintained at proper levels to insure the identification of danger by the general public. Ultimately, public awareness of gas odors and rapid response by first responders is the best defense for preventing an incident from occurring regardless of the cause of the gas leak.

Please feel free to contact us at any time in regards to this report.

Respectfully,

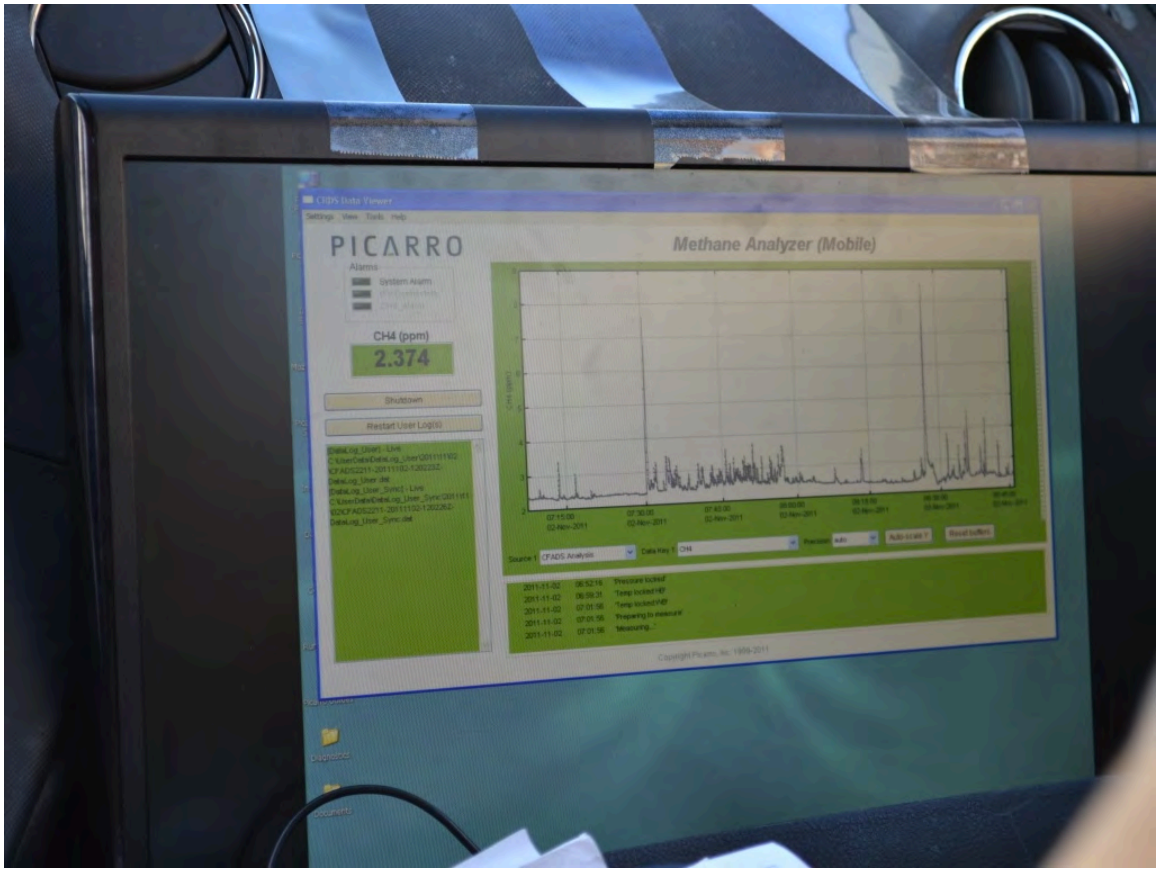
Robert C. Ackley
President
Gas Safety Inc.
16 Brook Lane
Southborough, Massachusetts 01745
508-344-9321
bobackley@gassafetyusa.com
www.gassafetyusa.com

Project Synopsis:

Picarro
Methane
Detector
Set Up

November 2-3, 2011

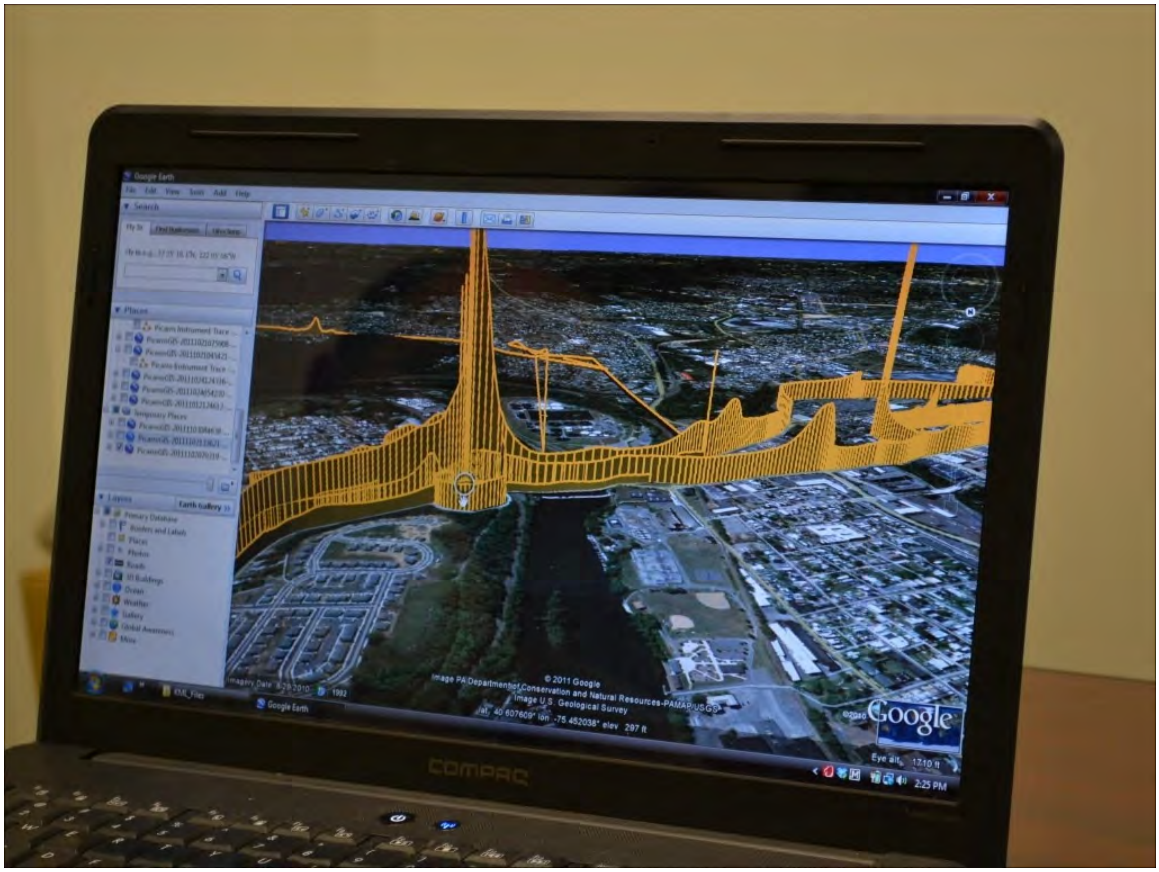

PICARRO


PICARRO
Methane Analyzer (Mobile)
CH4 (ppm)
2.374
Shutdown
Restart User Log(s)


INSPIRON mini
Real Time Google Earth KML depiction in Automobile


Bio Identification: dead and dying grass


26.0
AUTO ZERO
%OXYGEN
%LEL
%PGAS
TRACK GAS
S-SENTRY


Google Earth
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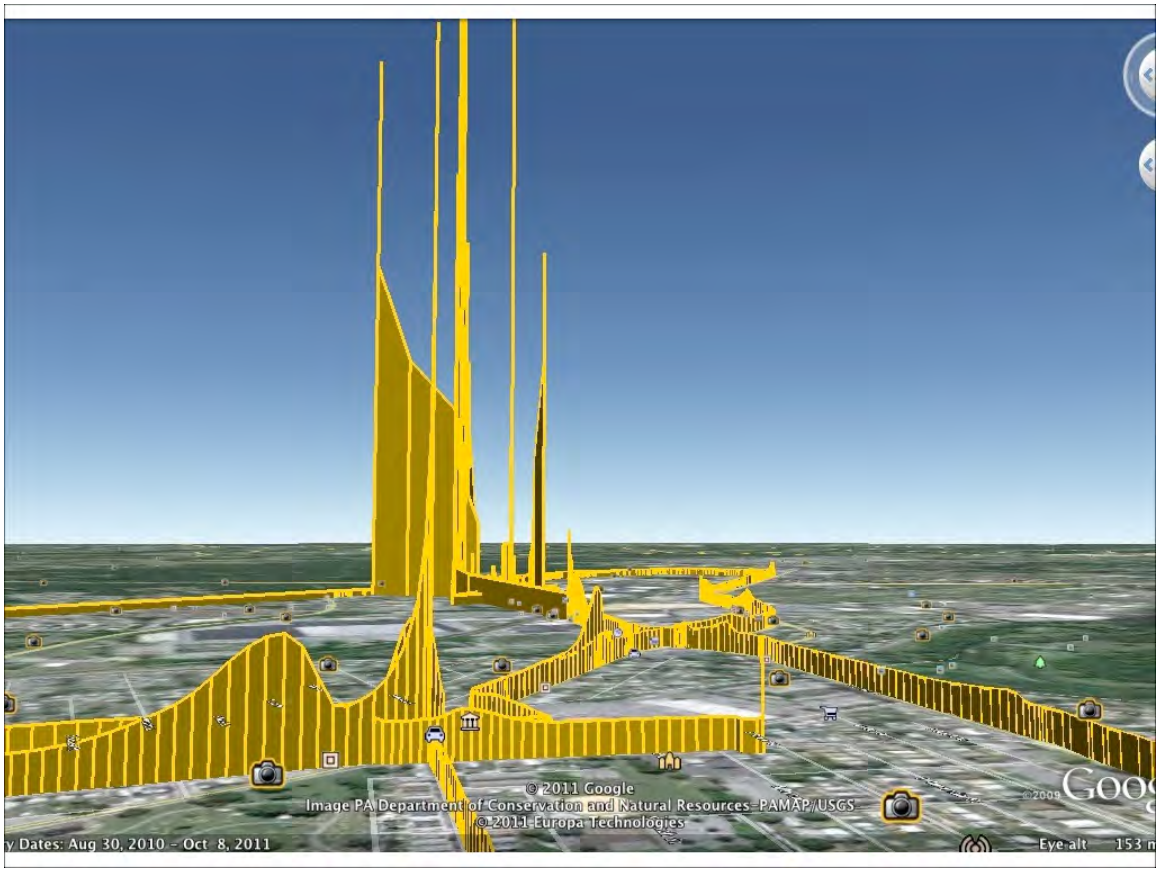
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