Tae Kim
Associate Counsel
Legal Department

April 5, 2016

VIA ELECTRONIC DELIVERY
Honorable Kathleen H. Burgess, Secretary
New York State Public Service Commission
Three Empire State Plaza
Albany, NY 12223

Re: Case No. 98-G-1304 - National Grid's Three Year Research, Development, and Demonstration Report

Dear Secretary Burgess:

The Brooklyn Union Gas Company d/b/a National Grid NY, KeySpan Gas East Corporation d/b/a National Grid, and Niagara Mohawk Power Corporation d/b/a National Grid hereby submit for filing their Three Year Research, Development, and Demonstration Report.

Please direct any questions regarding the enclosed report to Mary Holzmann, Principal Engineer – Gas Research, Development & Deployment at (631) 770-3449 or mary.holzmann@nationalgrid.com.

Respectfully submitted,

/s/ Tae Kim
Tae Kim

Enc.

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National Grid

Three Year RD&D Report

Prepared for

New York State
Public Service Commission

Albany, NY

Prepared by

Mary Holzmann
Principal Engineer
Gas RD&D

April 2016

Introduction

National Grid distributes natural gas to 2.5 million customers in Nassau and Suffolk Counties on Long Island and in Brooklyn, Staten Island and parts of Queens in New York City, and large portions of Upstate New York, including the cities of Albany and Syracuse. National Grid also distributes natural gas to 1.2 million customers in Massachusetts and Rhode Island.

In addition to its gas distribution business, National Grid owns and operates electric generation in Nassau and Suffolk Counties of New York State and also distributes electricity to customers in Upstate New York, Massachusetts and Rhode Island.

Goals of the RD&D Program

National Grid's Gas Research, Development & Demonstration (RD&D) program is designed to improve distribution operations. Targeted operations improvements involve enhanced public safety, cost reductions, improved worker safety, environmental and regulatory compliance. Within these broad areas, National Grid's ongoing research program focuses on the following technical categories:

- Damage Prevention. Technologies that allow the accurate detection of hard-to-find underground facilities such as plastic pipe with inoperable tracer wire, sewer laterals, or joints on cast iron systems. Technologies that warn of impending damage to underground gas facilities, or detect obstacles in the path of directional drilling machines
- Leak Location. Technologies that allow quicker, more accurate and less costly detection of leaks.
- Integrity Management. Various technologies to facilitate National Grid's compliance with the Pipeline Safety Improvement Act of 2002 and subsequent pipeline safety regulations which includes robotics, cased-pipe, material verification and integrity, improvements in asset tracking and traceability, TIMP and DIMP, crack detection, plastic pipe, and other risk and pipeline integrity management challenges.
- Live Maintenance and Repair. Live Repair technologies eliminate customer downtime by allowing repairs with gas mains in the live, operating condition.
- Trenchless Technology. Techniques that allow pipelines to be rehabilitated with minimal excavation.
- Gas Quality. The Company is engaged in various research projects to help prepare us for the expected changing picture in gas supply. The research is focused on the potential impacts that new supplies may have on our infrastructure and our customers.
- Environmental Technologies. New technologies that could be brought to bear on methane and advanced leak detection methods, residential methane sensors, manufactured gas plant (MGP) site remediation, monitoring, and other projects related to climate change.

- Infrastructure Support. Various projects targeted in improving infrastructure operations, corrosion control, construction and the tracking and traceability of underground assets.
- General Operations Improvement. Various projects targeted at improving operational safety, efficiency and/or worker ergonomics.
- Metallurgy, Welding, and Joining Process Improvements.

Projects active during the past three years within these categories, are described in the body of this report.

Execution of the Program

Most RD&D projects within these program areas are performed with a high degree of collaboration via the following research consortia:

NYSEARCH
NYSEARCH, whose members consist of 19 local distribution companies (LDCs) and one Pipeline Company in North America, is the research sub organization of the Northeast Gas Association (NGA). The NGA is a regional trade association focusing on education, training, research and development, operations planning and increased public awareness on natural gas in the Northeast US. NGA member companies collectively serve 9.5 million customers in eight states. NYSEARCH was originally created as a committee within the former New York Gas Group but has since become national in scope. In addition to the Northeast, NYSEARCH membership comes from the Middle Atlantic States, Mid-West and the West Coast and Canada. NYSEARCH focuses primarily on Operations projects. The NYSEARCH Staff of four project managers manage an active portfolio of projects within the program areas above. Member LDCs join projects at their discretion, commit funds according to their size, act as project advisors, and may host field demonstrations. For the NYSEARCH program, the Company's budget is set by first analyzing the projects that are approved. The project schedules are then established and a spending forecast is developed jointly with NYSEARCH. The company may contribute "in-kind" expenses towards a project in the form of field demonstrations and those costs are also considered. If a new project is still awaiting approval, a forecast is made of projected spending, again in conjunction with NYSEARCH.

Operations Technology Development (OTD)
OTD consists of 25 LDCs throughout North America and is an Illinois based not-for-profit (NFP) company administered by the Gas Technology Institute (GTI). GTI also performs project management services and researches about half the project portfolio. OTD focuses on operations projects. OTD Member LDCs join projects at their discretion, commit funds as they deem appropriate, act as project advisors, and may host field demonstrations. The OTD business model calls for an up-front pre-determined (based on company size) payment of annual dues each calendar year. For the OTD program the Company's annual dues are $750,000. As projects are approved they are funded by the annual dues. Unused funds can be used to offset the following year's dues. The company exercised this option for 2012.

A sub-program within OTD, the Sustaining Membership Program (SMP) is a longer term GTI program focusing on basic science, which usually results in a proof of concept that which is further developed in the OTD program. National Grid terminated its participation in the SMP program effective January 2013.

In some cases, National Grid may choose to enter into development contracts with research providers jointly with other LDCs or by ourselves.

NYSERDA

The Company is currently assessed an annual amount of approximately $4.9 Million for the NY State Energy Research and Development Authority (NYSERDA). The assessed rate is based upon NYS Intrastate Revenue – (Sales for Resale and Transmission for Others). The Company has no say in which projects are funded through the NYSERDA program. However, the company monitors the various NYSERDA Project Opportunity Notices (PONS) and may elect to submit a proposal to NYSERDA for cofunding a Company RD&D project.

Funding

Part of National Grid's ongoing RD&D program is funded via the "Millennium" Fund and surcharge, authorized by the New York Public Service Commission's February 14, 2000 Order in Case 99-G-1369 (the "Millennium Order") to replace the mandatory FERC pipeline research surcharge. A maximum allowable collection rate of $0.0174/dekatherm on firm transportation and sales is the source of funding for the program. National Grid currently collects $0.0067/dekatherm from its KEDNY operations and $0.0000/dekatherm from its Long Island and Upstate Operations. The winter of 2014-15 was unusually cold with extended periods below freezing. This caused the collection rates, which are tied to dekatherm usage, above the current spending levels for a period of time. Additionally, a great deal of R&D focus has been on residential methane detectors which is not being funded through Millennium but is being funded via company funds through the Long Island Settlement Agreement instead. So we have decreased the collection rates in KEDLI and NMPC in order to levelize balances with current R&D commitments. Since the last report, the changes in spending levels are in part due to National Grid Downstate has been funding the majority of the development of the Explorer 16/18 inch internal inspection robot for un-piggable pipelines in this range of larger diameter transmission piping. While this project benefits our Upstate territory, the larger share has been funded through the Downstate surcharge due to the larger inventory of 16 inch un-piggable pipe there. More recently, projects looking into the use of drones in gas operations will be of greater potential use in our Upstate NY area which will shift R&D investment dollars to Upstate as that work progresses.

Unlike the phased-out Federal Energy Regulatory Commission (FERC) surcharge, the Millennium fund is controlled by National Grid and spent on eligible projects via NYSEARCH, OTD, GTI or other research providers at National Grid's discretion. As specified in the Commission's Millennium Order, in order to qualify for Millennium

funding a project must be medium to long term in nature (i.e., projects that are at least twenty-four months or more from becoming a commercially deployable product); 80% of Millennium funds must be spent on co-funded projects and cannot be directed to fund natural gas appliance research or supply/storage projects. The projected budget for the next three years averages $2.7 Million. The Company realizes a high degree of cofunding from other participating LDCs, and from the US Department of Transportation (DOT) Pipeline Safety Research Program. Because of this, the Company's leverage is about 7:1, meaning for every RD&D dollar we spend we realize seven dollars of overall RD&D funding.

National Grid maintains an internal budget to fund projects that do not meet the criteria set forth in the Millennium Order. The budget is $183,000 and typically funds short term "quick hit" RD&D efforts, association (NYSEARCH) dues, and patent protection fees.

Attachment 1 shows actual and projected spending for the Company's Gas RD&D program, Internal, External (NYSEARCH and OTD) and the NYSERDA Assessment.

Program Management

The management and administration of the operations program is by National Grid's Gas Materials and Standards, group within the Gas Engineering/Network Strategy organization. Subject matter experts throughout the company are used as needed when specific technical expertise is required on projects.

Selection of Projects

The Company uses four criteria to judge the merits of RD&D projects. The first is safety. Some projects are undertaken to enhance the safety of workers in the field, or the general public.

The second criterion is compliance with regulations. An excellent example of this is the transmission pipeline safety regulations. In the Pipeline Safety Improvement Act of 2002, Congress directed the US Department of Transportation to establish and promote a research partnership with industry to develop tools and techniques to improve pipeline safety. Ensuring the highest level of pipeline safety requires tools and techniques that have been developed over the last 10 years, such as the robotics program for internal inspection of unpiggable pipelines.

The third is increased knowledge about gas operations which can lead to increased efficiencies, material improvements and or better techniques for conducting daily operations.

The fourth criterion is financial benefit. The R&D budget is looked at based upon historical spending levels and is adjusted depending upon if there is an increase or decrease in current challenges being addressed and priorities that require research

investment are funded. The Company may use a benefit/cost (B/C) ratio test to determine whether RD&D projects should be adopted into our operations. Benefits are the net savings in operational costs that are realized via implementation of new technology. Costs are the project costs to fund and implement the new technology. In some cases R&D studies can also lead to operational savings and the same B/C test applies. However, not all studies have a definitive cost benefit. Studies may lead to increased safety measures or process improvements.

Most projects have multiple benefits, for example, projects undertaken for worker safety can lower injuries and reduce sick time (thereby providing a financial benefit), and compliance with regulations can improve safety of the gas system and the public. A project with a marginal financial benefit may also be approved if it meets one or more of the other criteria.

Benefits

National Grid, in collaboration with other funders, has been involved with bringing the following products or increased knowledge to market over the past few years:

- Keyhole Tools and Methods
- Pipe Splitter
- PFT Chromatograph for Leak Detection
- No-Interrupt Service Transfer (NIST) Tee
- Cured in Place Liner Improvements
- Butt Fusion Repair Sleeve (BFRS)
- 4" and 6" Variable Length PE Repair Sleeve
- Remote Methane Leak Detector (RMLD)
- Studies on Plastic Pipe Performance
- A Full Suite of Live Internal Gas Main Video Inspection Devices
- NYSEARCH/Kiefner Interacting Threats Modeling Software
- Cased Pipe Integrity Assurance Model
- Explosion Proof Light Fixture
- Guidance Document on Biomethane
- Explorer Suite of Inspection Robots for the Inspection of Unpiggable Pipelines – Pipetel Technologies, Inc. EXP 6/8, EXP 10/14, EXP 16/18, EXP 20/26, EXP 30/36, Supporting Technologies and enhancements in detection capabilities
- Cased Pipe Annular Space Inspection Robot
- CISBOT
- Acoustic Pipe Locator
- Metallic Joint Locator

Active Project Discussion

Internal Budget – Non-Millennium – NYSEARCH Projects

Projects that do not meet the criteria set forth in the Millennium Order (i.e., medium to long term and no end use or appliance funding) are funded via National Grid's internal budget. Internal projects (also referred to as Non-Millennium or Traditional R&D) are research that is of short term duration (work that is expected to be completed in less than 2 years) or work that is appliance or storage related.

T759 - Ergonomic Study to Develop and Test a New Design Needle Bar. A needle bar is a manually operated tool used to make small diameter holes, called barholes, in paved or unpaved areas over gas mains to allow pinpointing of leaks. During a typical leak investigation as many as 15-25 such holes may be required. The repetitive up-down motion required when using the tool is often a source of soft tissue injury if the user fails to maintain an upright position when using the tool. An ergonomic needle bar with a ratcheting handle was developed. This tool allows the operator to remain in an upright position for the duration of time it takes to create a barhole. The drawback is that the tool is heavier. Field trials were conducted throughout the National Grid territory and the tool failed to gain universal user acceptance. However, these efforts have stimulated manufacturers to continue working independently working towards more ergonomic tool design. The benefit of this work is a reduction in soft tissue injuries.

T763 - PE Rock Impingement Study. A study was undertaken to determine whether the requirement for clean backfill around polyethylene (PE) pipe could be relaxed given the high resistance to slow crack growth demonstrated by modern PE materials. In many situations, a common practice is to truck in clean, screened backfill in lieu of using native materials, at an increased cost. Testing performed in Europe has demonstrated that modern PE materials have such superior resistance to point loadings that use of select backfill is no longer required. No such testing had been undertaken in the US so, through NYSEARCH, Jana Labs was commissioned to perform the tests. Medium density and high density PE pipe, which is representative of the PE pipe installed now at the Company, were subjected to extreme point loading to simulate contact with rocks which could be present in native backfill. (Test loadings were so severe that the indentation was visible at the interior pipe wall.) The sample pipes were then pressurized and hot tank tested (standard testing protocol – which compresses many years of testing into a relatively short time period). Tests have shown no harmful effects from extreme simulated rock impingement loading and the projected time-to-failure in normal operating conditions is well in excess of 100 years. This work is an excellent validation of the superior toughness of modern PE materials. Significant cost savings have already been experienced in the Company's New York City Operation.

T764 - Auto Gas Lamp Field Evaluation. Working through NYSEARCH, the Company undertook an evaluation of a gas lamp for street lighting that was equipped with an igniter and a photo sensor which would shut off during daylight hours and reignite in the evening. Independent testing confirmed that the lamp and igniter system performed well in lab testing and several lamps were deployed in funders' territory. The benefit of the project is a savings of natural gas during daylight hours, a corresponding reduction of CO2 emissions, and improved customer relations and satisfaction.

T765 - Gas Interchangeability Study for Installed Residential Appliances. The addition of new gas supplies (imported LNG, unconventional gas) is expected to accelerate, leading to wider ranges of natural gas compositions. While the industry is expanding supply sources, to date there has been no standardized approach for evaluating the impacts of varying gas compositions on in-service residential gas appliances. The benefits of such a study are to determine the extent to which potentially sensitive appliances exist and to identify which specific appliances are affected based on type, vintage, adjustment practices, and maintenance characteristics. With that information, better decisions can be made about whether adjustments are necessary to those appliances in order to successfully accommodate varying gas compositions. The project consists of two phases; in Phase I, over 2400 appliances were visited in the field and firing rate, percent excess air, CO and NOx formation were measured and flame quality was observed. In Phase II, lab testing was performed on selected appliances (about 20) subjecting them to a wide range of future expected gas compositions to determine their performance. This phase of the study yielded important information about how typical appliances will perform over a wide range of gas compositions and benefits the company by allowing it to more effectively negotiate future tariffs and plan for remedial actions for more sensitive appliance types. This work is nationally recognized. Project results have been shared with the American Gas Association (AGA) and key findings will be incorporated into the next revision of "Bulletin 36," which addresses gas interchangeability concerns. Based on the results of this work an appliance assessment software tool is now available on the NYSEARCH website. NYSEARCH RANGE™ is one of the deliverables of the NYSEARCH Gas Interchangeability for Appliances project which studied and modeled how changing gas composition can impact the performance of in-service residential appliances. This risk assessment model is available to purchase for on-line use.

T766 - Technology Transfer Improvements. An ongoing study to investigate specific member lessons learned with successes and failures of technology transfer and to share procedures so that more companies can be successful with a process for cultivating company support and longevity in implementing new technology

T768 - NYSEARCH/Kiefner Interactive Threats Project. The project defined and prioritized interacting threats that impact pipeline integrity. A more robust treatment of interacting threats was incorporated in risk models. To ensure that the NYSEARCH/Kiefner Interacting Threats model stays current, PHMSA's annual incident and Kiefner's forensic failure databases are being checked and incorporated into annual software version upgrades.

T769 – Test Program for Picarro Leak Surveyor. In early 2012 the Company became aware of a new technology for leak survey manufactured and marketed by Picarro Corp. The technology is vehicle mounted laser based sensing of methane at sensitivity levels never achieved before by standard leak detection technology. Methane at 30 parts per billion (PPB) above background concentrations can be detected. Along with methane sensing, this vehicle based technology also records atmospheric conditions such as wind speed and direction, temperature, humidity and cloud cover. When methane is detected

the Picarro technology plots out an area that should be investigated and pinpointed. The area to be investigated is based on the methane concentration that was detected, and the atmospheric conditions, such as wind speed and direction. This gives operators a good idea from which direction the methane is coming.
Through the NYSEARCH consortium, the company and others wanted to do a side-by-side comparison of Picarro technology to existing distribution leak survey methods in use at the Company. A double blind test protocol was established and for two days the standard company leak survey procedure – which is a walking survey using Bascom Turner "Rover" leak detector – was run on the same days on the same streets as the Picarro mobile survey technology. Results of the comparative surveys for the Company and other project participants have been compiled. No report can be released due to legal agreements with Picarro. This project was completed in Nov. 2014.

T-770 - Technology Transfer, Demonstration & Post Mortem Testing of Cast Iron & Steel Pipe Lined with Cured-in-place Pipe Liners. See details under Live Inspection, Maintenance and Repair section.

T-773 - Trenchless Replacement of Small Diameter Steel Gas Service Lines. See details under Trenchless Technology section.

T-774 - Impact of Gasoline/Oil on PE Pipe. The objective of the project is to understand the impact of external contaminated soil conditions on the external surfaces of PE pipe and develop a practical engineering and operator's guideline that provides specific instructions for evaluating in-service PE pipe exposed to contaminated soils.

National Grid Study on Risks Associated With Natural Gas Appliances Immersed In Water. Flooding and flood damage are not unusual events in the United States (U.S.). According to the National Oceanic and Atmospheric Administration (NOAA) and the National Weather Service (NWS) data, annual flooded property losses exceed $7.8 billion on average during the past thirty years. Major episodic events such as Hurricanes Katrina and Sandy can substantially raise losses and place substantial strain on natural gas and electric utility operations due to the extensive damage done to delivery infrastructure and customer equipment. This study was undertaken to help qualitatively assess the failure modes and potential risks associated with natural gas appliances immersed in water for extended periods. Survey questions were used to facilitate interaction with several natural gas furnace, boiler, and water heater manufacturers.

In general, funding for "internal projects" is used to pilot new products and technology—e.g. keyhole, live main insertion, leak sealants, or to perform short term studies. Any appliance related work would also be internally funded.

Millennium Program

NYSEARCH and OTD Projects

Damage Prevention and Pipe Location

According to the US Department of Transportation (DOT), third party damage is the primary cause of pipeline incidents on LDC distribution systems, accounting for over one third of all reportable incidents. Repair costs due to Third Party Damage are estimated at $10 Million annually, and often result in loss of service to customers. National Grid is funding the following efforts:

M2001-005 – Handheld Pipe Locator using Ground Penetrating Radar (GPR). GPR is high frequency electromagnetic radiation that has proven capabilities to detect underground features but no hand held GPR device existed. The goal of the project is to develop a user friendly GPR device that can be deployed by field crews when standard locating technology cannot precisely locate suspected underground facilities. A portable, light-weight free scanning plastic pipe locator for use by LDCs and construction crews to identify the lateral position of hard-to-find plastic pipe (can also locate other metallic pipe). The target application for this technology is plastic pipe with inoperable tracer wire. Such pipe cannot be located by standard "clip-on" locating technology. The product has been designed, developed and tested. NYSEARCH worked with Pipehawk LLC, a UK company, to develop the technology but attempts to commercialize it in 2006 were unsuccessful. Difficulties arose when attempting to transfer this product to a commercializer for engineering improvements (such as ergonomics) and preproduction testing. Another potential commercial partner, Sensors and Software, a recognized leader in both development and manufacture of GPR locating equipment, had been engaged to explore potential commercialization. This contractor is now assessing the feasibility and potential market for this technology. A successful device would provide company crews with the ability to quickly locate plastic pipe without tracer wire. After multiple attempts with a selected contractor who had interest in commercializing, no additional work or funding was promoted.

M2002-011 PhIII - FFT Damage Prev Monitoring - Advances with Aura. Damage Prevention and particularly proactive monitoring for third party intrusion near transmission and distribution pipelines is a high priority for many gas companies. Due to interest expressed by members in revisiting the FFT's fiber optic intrusion detection system, and in particular its advanced system known as Aura™, NYSEARCH renewed this project (renewing the former FFT project that worked with the Secure Pipe product) to test this higher resolution distributed sensor product as it applies to two different test sites with different conditions; one at Woodbridge NJ in PSEG's territory and one in Ontario in Enbridge's territory. Tests and results are finalized. Final Reports for PSEG complete; final report for Enbridge work pending.

M2002-018 - Proactive Infrasonic Sensor This system consists of seismic sensors that can be installed near critical gas mains or other facilities and can sense activity near those facilities and send a warning to a control center or other company facility. The system is "trained" to distinguish benign threats (truck traffic, etc) from real threats. Comparable systems on the market now differ in one important distinction; they all require physical contact with the sensor, this system will detect activity as far away as 300 ft. Benefits of this project are reduced incidences of third party damage and associated repairs.

M2007-007 Advanced Video Surveillance (A-Gas) System. This project uses a video image approach to detect possible third party damage. Standard video cameras are trained on an area of concern and proprietary software is used to "learn" the scene so that normal activity can be discounted but abnormal activity alarmed. The A-Gas system is available for security applications. The research component of this project is to adapt the technology to the new concept of advanced warning to LDC operators of potential third party damage. In a second phase of the project we are working with the vendor to develop an environmentally hardened version of the camera/software system which can be mounted outdoors without any special environmental enclosures. The benefits of this project are reduced incidences of third party damage and associated repairs.

M2008-001 – Advanced Development of PipeGuard™ – Proactive Pipeline Damage Prevention. This system by Magal/Senstar is technically similar to the Proactive Infrasonic Sensor system but is a commercially available system that is used for security applications. The goal of this project is to adapt this security based technology for use in the natural gas industry to be utilized in an underground surveillance mode to detect occurrences at or near the surface to alert the operator of third party activity, presumably excavation, in the vicinity of the installed sensors. This project includes the evaluation of a geophone-based pipeline monitoring capability that will warn an LDC of impending damage to pipeline facilities. Following the initial technical feasibility assessment, through NYSEARCH, the Company is hosting a demonstration site on Long Island to test this technology adaptation. The target goal for detection alarms for backhoe, pneumatic piercing tools, and pavement breakers is 250 feet from the sensing units. This will provide total monitoring coverage of 1000 feet along the pipeline run when two sensing units are installed. It is expected that detection distances for shovels and manual post-hole digging tools will be significantly lessened. Benefits of this project are reduced incidences of third party damage and associated repairs through proactive monitoring in advance of actual work performed by a third party.

M2011-005 – Fiber Sen System Development and Testing In the last 10 years advanced damage prevention technologies using fiber optic cable have been marketed. Most of these technologies are suitable for extremely long lengths of transmission piping and one system even uses satellite transmission of data to a central monitoring site in Europe. Systems such as this do not meet the needs of the Company. Through NYSEARCH, the Company became aware of Fiber SenSys Inc., who is interested in developing a shorter version of existing technology which would be more applicable to the needs of distribution companies.

Fiber SenSys proposed to develop a fiber optic cable which can be installed parallel to an existing gas transmission main, or alternately the cable can be incorporated into a new main installation. The system functions by detecting vibrations in the soil around the pipeline. The vibrations alter the characteristics of the laser light in the cable and can be detected and alarmed. Requirements are that the system be able to detect presence of commonly used excavation equipment, while recognizing and filtering out other acoustic signals that would be generated by benign threats such as truck or rail traffic. The system

must perform in all types of soil that can commonly be encountered in the Company's territory. A NYSEARCH member company has offered a test site where a prototype system can be installed and tested. The target cost of the system, depending on length monitored, would be as low as $3000 per mile. The benefit to the Company is enhanced damage prevention and potential avoidance of a major pipeline accident due to third party damage. This project expanded on lessons learned from a prior project related to proactive monitoring for third party damage using fiber optic sensors. The project developed a system for shorter runs of pipe based on the contractor's (Fiber Sensys's) system for longer runs of pipe. The 'short ranger' system was tested and evaluated for gas distribution applications and its technical and economic feasibility was studied.

M2011-008 – BioBall Test Program. A NYSEARCH member company has worked with a technology company to develop a simple technical approach to accurately locate sewer laterals. The technical approach is to simply wind a length of copper wire on to a biodegradable "spool" which can be flushed down a commode in a residence. The wire will unspool and standard locating equipment can be connected to it and the location of the sewer lateral can be determined. NYSEARCH member companies want to determine whether the idea is feasible and have funded a test program. The Company has conducted a week long field test program on this technology. Results were mixed; in many cases gaining access to the residence was problematic. In those cases access to the sewer lateral was through an outside cleanout. Where the bioball did deploy successfully, location of the lateral was determined within +/- 2 ft. Interest in this project is high because of a concern with "crossbores," in which pipe installed via directional drilling inadvertently punctures a sewer lateral. The situation may not be detected for years until the sewer line clogs and a plumber is called by the homeowner, with potentially disastrous results. The benefit of this technology is accurate location of sewer laterals and subsequent avoidance of a crossbore.

OTD 1.8.a - GPS-Based Excavation Encroachment Notification This project focuses on linking Global Position System (GPS) technology with digging operations to provide a warning system to prevent excavation damages to underground facilities. The objective is to develop and demonstrate a system to ensure that excavation activities are occurring within a valid "One-Call Ticket" area (which authorizes excavation) and are not encroaching upon underground pipes and facilities. The Company and other project funders are partnering with Virginia Utility Protection Service (VUPS), a "one-call" center for utility locates, that has been conducting pilot programs to demonstrate the feasibility of using GPS-enabled cell phones (Phase 1) and GPS-enabled locators (Phase 2), and excavating equipment (Phase 3) to call in excavation projects, access information, and prevent unauthorized excavations. The benefits of this project are more accurate and smaller "white-line" (areas needing markout) areas, more accurate locating, and warnings to excavators if they are excavating in unmarked areas. All of this reduces the threat of third party damage. The company is participating in a follow on project to implement a similar pilot program in upstate NY.

OTD 1.h and 1.10.c – Hand Held Acoustic Pipe Locator. Plastic pipe without tracer wire remains a vexing problem for LDC locating crews because standard electromagnetic locating techniques will not detect plastic pipe. Ultrasonic waves are ideally suited for this application because they will travel well through solid mediums (soil) but are reflected off of voids, air pockets or lighter density materials. The acoustic locator has shown that it can reliably detect plastic pipe. A follow on to this project (described next) will target location of sewer laterals, an important issue lately as more LDCs are using directional drilling to install gas mains. Accurate location of our buried facilities is the main benefit of this project. Completed 2013.

OTD 1.10.e – Enhancing Damage Prevention in New York. The objective is to conduct a pilot project to demonstrate the procedures and technologies for implementing an electronic as-built process and radio frequency (RF) tag based asset locating system. The proposed technology will automate the as-built process by using new high-accuracy GPS technology and aerial photography to document the location of newly installed facilities. RF tags will be used to enhance the locating and mark-out process by providing field personnel with additional asset location information. Phase 3 will develop a prototype system that allows the collection of highly accurate spatial data in urban canyons where traditional GPS technology is ineffective.

OTD 1.11.e - Crossbore National Database and Risk Model. As crossbores, where a natural gas line installed via trenchless construction methods, has penetrated a sewer main/lateral. For example, homes with sloping front yards and no basements may have sewer laterals that are close to the surface and therefore more likely to be intersected by a horizontal directional drilling operation. The objective of this project is to gather as many parameters as possible associated with crossbores actually identified in the field. In addition to the Company, other LDCs are gathering data on crossbores. There has not been a unified effort nationally to collect this data. By combining this data into national database users can identify those situations and field conditions where crossbores are more likely to occur in its own territory, and can prioritize and focus remedial action on the highest risk areas. The purpose of the database is to collect information on crossbores root causes, environmental and situational factors, and compile incident reports to facilitate the sharing of lessons learned and increase public safety.

OTD 1.12.b – Crossbore Detection Using Mechanical Spring Attachment
In the concluding phase of OTD 1.11.a, "Evaluation of Chemical Detection Methods for Detecting Sewer Lateral Crossbores," one of the project funders suggested a brainstorming session for innovative ideas to detect crossbores. The leading idea is to use a simple spring loaded sensor on a drillhead that would "snap open" upon encountering a void, such as would happen if the drillhead suddenly penetrated a sewer lateral.
GTI engineers will design and test a prototype tool that will detect a hit to sewer laterals during the HDD or mole installation of PE gas pipe. The tool utilizes a low-cost and easy to use mechanical system that is attached to the HDD/mole head during drilling or to the PE pipe during pullback. The mechanical system is activated inside the sewer pipe void; thus locating the lateral and providing a real-time alarm identifying a hit. At the conclusion of the project, commercialization activities will begin. A simple yet accurate

method for detecting a crossbore in this fashion is a tremendous benefit to the company because crews are present to immediately rectify the situation.

Leak Detection and Methane Emissions

Rapid and more accurate leak detection and location (pinpointing) has always been a research focus for the industry and for National Grid in particular. We are funding the following efforts:

M2010-002/T-776 – Methane MR Sensor/ new Residential Methane Detector Development Program. NYSEARCH/NGA has been developing a small, reliable, intrinsically safe, line and/or battery powered, miniature methane (natural gas) sensor based on micro-resonator technology that measures the viscosity of a gas mixture. The sensor would be used in detecting natural gas leaks and other applications. The instrument is being developed for two applications; an analytical sensor for measurement with data output, and as an improved safety sensor for use in residential applications. Due to the high reliability and resistance to false alarms, this program has shifted its focus entirely to the residential sensing application. Following extensive testing of advanced prototypes, precommercial prototypes are being tested by UL and a pilot test program is being implemented following completion of UL testing. This project has produced a novel type of methane sensor using the principle of micro-resonance. The theory behind the sensor is that micro-size tuning forks will vibrate at different frequencies when exposed to a methane/air environment than it would in free air. This concept was uncovered during a technology search undertaken as part of the "Oracle" project. After extensive testing it has been found that this methane sensing device does not exhibit false positives in the presence of many household chemicals which is makes it superior as safety device over currently commercialized devices. It has not demonstrated any false positives.

The sensor is capable of measuring the methane concentration from 0% to 100% in air at different pressures, relative humidity levels and in a wide temperature range. The measurement range of primary interest corresponds to 0-100% Lower Explosive Limit (LEL) with the ability to measure gas concentrations up to 100%. [LEL for methane corresponds to approximately 5% methane/natural-gas concentration in air.] The sensor has a detection limit and an accuracy of 0.25% natural gas concentration in air. The sensor is capable of operating at various gas gauge pressures ranging from 30 to 110 kPa and temperatures of -20°C to 50°C. The response time of the sensor is targeted at 1 second or less. To verify and validate the performance of the MR Methane detector (safety sensor/alarm monitor) a pilot testing program will be implemented. Detectors will be deployed in residential settings to test them under real life conditions under a variety of operational conditions and environments. The following issues will be addressed: (a) having a sufficient number of installations, (b) covering a wide range of housing types, (c) evaluating different detector locations within the homes, (d) selecting locations that expose units to possible interfering chemicals (e.g., masking, false positive) and potentially damaging conditions (e.g., humidity, temperature, chemicals, insects), (e) considering the impacts of ventilation rates and air flow patterns in homes, (f) monitoring

performance in all seasons, (g) monitoring performance at various elevations, and (h) validating detector performance before, during, and after the field trial.

M2014-002 - Leak Pinpointing Inside Pipe. The overall program goal is clear to design, develop and test an innovative system that can precisely locate gas leaks from inside the pipe. The selected technology needs to apply to a range pipe sizes, 2" – 12" in diameter. During testing the experienced JD7 operator inserted the instrument into the flow loop through an ALH/WASK valve fitting after the simulated leak was created and covered. The first round of testing was designed to determine if the JD7 could detect leaks of various sizes and pressures. This initial round of testing was performed without air flow (fans were off). The JD7 proved capable of detecting leaks as low as 6" water column pressure leaking at the rate of 0.12 scf/hr. and at our top simulated pressure of 40 psig with a leak rate of 52.5 scf/hr. The JD7 was also capable of detecting leaks at various pressures and leak rates in between these upper and lower tested limits. A second round of testing was performed. The JD7 was manually inserted down the test pipe and located the leak without knowledge of the leak location. This testing was conducted without air flow and with air velocities of 2.5 mph (one fan) and 12 mph (both fans). The JD7 located leaks at no flow as small as; 1) 0.70 scf/hr. at 12" water column and 20 psig, 2) between 5.23 and 8.33 scf/hr. at 2.5 mph air velocities at both 5 psig and 40 psig, and 3) at 12 mph air velocity with a leak rate of 52.5 scf/hr. at 40 psig. Although initial flow loop testing of the JD7 at Heath was a success, improvements should be made to the JD7 Gas Investigator in a proposed Phase II of this project in order to improve its efficiency of operational performance. These improvements should subsequently be blind tested in a buried flow loop containing simulated leaks with the capability of varying pressures and flows.

M2014-004 - Technology Evaluation and Test Program for Quantifying Methane Emissions. The overall objective of the project is to identify, test and validate what technology or technologies are available that can be applied from a mobile platform in an urban environment to quantify methane emissions rates.

M2015-002 - SRI Standoff Gas Flow Imaging and Analysis System. The overall objective of the approved program is to quantify the flow rate from gas distribution leaks using the schlerien optical imaging technique as applied on a portable, field-usable system.

OTD 1.9.a – GPS Based Leak Survey. The objective of this project is to develop and utilize a software application that automates leak surveying with GPS. Using standard GPS receivers a leak surveyor's route is automatically uploaded to company maps and a permanent record of the actual route surveyed is created and preserved. The application attaches GPS coordinates to survey routes and leaks while electronically documenting work to demonstrate compliance. The application also allows the user to create and populate an electronic leak form that can be directly transferred to a back-office leak management system or a Geographic Information System (GIS). New leak detection equipment that is on the market will be linked via software to company maps or images to automatically track routes of leak surveyors, thereby creating a traceable record of survey routes walked. The benefits of this project are reduced time for documentation and more accurate record keeping.

National Grid funded an additional phase of the project to conduct an actual field trial of the technology in a select area in New York City. Due to Hurricane Sandy, the pilot was delayed until April 2013 and was completed in August 2013.

OTD 1.11.c - Methane Sensor The goal of this project is a low cost reliable methane sensor for in-home use or use in company facilities (gate stations etc.) to detect and alarm on the presence of methane in air. Instruments are available to do this but typically can be set off by non-methane hydrocarbons which could be present in a house basement, paint thinner or hairspray for example. The testing protocol was designed to test the accuracy and stability of the six KWJ MEMS sensors by testing them at various methane concentrations, different temperatures, different relative humidities, and different interfering gases. In order to execute the testing protocol a testing chamber was designed to monitor and control all of the different conditions. After the completion of several basic testing conditions, the project team concluded that further testing should be terminated. Termination of the testing was recommended for several reasons. Because of our concerns on the path forward of this project, National Grid elected not to continue this effort.

OTD 1.14.d - Field Measurement of Leak Flow Rate. The goal of this project is to develop an inexpensive and repeatable device that can provide a measurement of the gas-leakage rates in the field from Class 2 and 3 non-hazardous pipe leaks. The current phase of the project involves improvements on an alpha prototype and upgrading the technology to provide increased accuracy, precision, lower cost, and ease of use. In 2015, an enhanced prototype was placed in a test chamber and subjected to varying levels of methane at constant temperature and humidity. The prototype is Wi-Fi enabled and presents an access point that the user can log into. A web page is presented that displays the parameters being measured by the prototype and allows control of the sampling fan. This allows access to the prototype through a device that supports Wi-Fi and a web-browser. Additional work was performed in the area of calibrating the Figaro methane sensor that is used in the prototype. The goal is to develop an accurate calibration curve that relates the raw sensor output voltage to % LEL with corrections for temperature variation. The current version of the prototype measures the flow through the device accurately but is somewhat limited in the range of flows achievable. The flow sensor represents a constriction in the measurement path of the prototype. At this time a high-powered fan is required to draw samples through the system. GTI is currently considering replacing the thermal flow sensor with a rotating vane type that would lower the requirement on the fan and consequently on the overall power consumption.
The alpha prototype was demonstrated to OTD at the fall 2015 meeting. — A basic demonstration of the Phase 2 beta prototype is planned for the fall 2016 OTD meeting.

OTD 1.14.g - Residential Methane Detectors Program. In this program, several discrete initiatives are being addressed as tasks, with the initial work being a consumer behavior study to better understand how customers react to potential leaks and the development of a “Fit-for-Purpose” standard for residential methane detectors. This program also includes a comprehensive pilot program to evaluate commercially available

detectors that performed well during laboratory evaluations. — A pilot testing program is currently under way, with detectors being placed in residential homes throughout the U.S.

OTD 1.15.e - Triple+ Shutoff Valve Pilot Program. Triple Plus Ltd. has made available the Triple+ NGL™ version 4.0 of its gas leak management system, a product capable of detecting gas leaks and automatically shutting off the gas supply and stopping the leak. The objective for this project is to perform controlled testing of the valve portion of the product. Researchers are collaborating with Triple Plus to evaluate a technology that combines a methane detector with an automatic shutoff valve as a safety solution to prevent risks due to leaks and other events (e.g., hurricanes, earth-quakes, floods). This unit is assembled in-line with existing gas systems. If a gas ball valve is installed, there is no need to cut, replace, or remove existing pipelines or valves. — Plans are being made for a testing program with OTD sponsors.

OTD 5.14.j - Residual Gas Removal - Identify Technologies, Limitations & Best Practices. This effort reviews current and new venting equipment and strategies utilized by gas operators to effect safe and timely extraction of in-ground residual gas. The presence of residual in-ground gas poses hazards to the public and nearby infrastructure, complicates leak pinpointing efforts and obfuscates effectiveness of performed leak repairs. A lingering presence of odorized gas can also generate secondary leak reports by the public for extended periods after a leak repair has been completed. Numerous equipment and strategies for venting and dispersing residual in-ground gas exist. A number of field visits to residual gas mitigation job sites were made to evaluate current practices and provide best practice guidance to the industry. In light of findings from industry surveys and sponsor discussions, the frequency of residual gas mitigations requiring more than natural venting strategies such as that provided from barholing, trenching or the use of vented manhole covers, was significantly lower than anticipated. Other traditionally employed devices such as aerators and air movers, that utilize pneumatic power to generate suction via the Venturi principle, are highly effective in the bulk of residual gas extraction scenarios. Though ultimately dictated by local soil and site conditions, the need to utilize dedicated or higher flow capacity vacuum extraction approaches is minimal and reflected by slow market uptake of specialty equipment such as Vapor Extraction Unit (VEU). Safety aspects and some factors dictating how best to elevate extraction efforts in dealing with persistent in-ground gas indications at the site of repaired leaks are summarized in the project report. Due to the low frequency of this issue and demonstrated effectiveness of the most simple, low cost strategies in the majority of residual gas removal scenarios faced by operators, it was agreed that there is no need to propose follow-on quantitative evaluation of techniques as of Q1 2015.

OTD 5.14.w - Testing Program for Valve with Water Sensor for Storm Hardening. In this project, researchers are evaluating a valve integrated with a water sensor to assist with storm hardening. Phase 1 testing was completed in 2015. Additional phases will be addressed based on development status and needs of the project sponsors. Evaluations involve a battery of tests, including: visual tests, pressure tests, debris tests, water-intrusion tests, corrosion tests, humidity testing, drop tests, and others. — A Phase 1

Final Report was issued in August 2015. Additional work continues in the development and addition of methane sensor to couple with the valve actuator.

OTD 7.15.b - Remote Gas Sensing and Monitoring for First Responders. The safety of workers, first responders, and the general public will be greatly increased by being able to monitor the atmosphere of buildings and other structures remotely. In addition, continuous remote monitoring of various gas levels during known gas leak situations will allow for better and quicker analysis of the situation. The remote sensors can be placed and/or operated in multiple buildings, sewers, and other structures in the area of the known gas leak. The remote device can wirelessly provide real-time information back to first responders, gas company personnel and others in charge of monitoring and assessing the gas levels in the structures. The objective of this project is to create a device to remotely monitor the level of gases during emergency situations. The device will provide critical information to first responders and gas company personnel, allowing them to determine the concentration of methane, CO, and possibly other key indicators inside buildings, sewers, and other structures from a safe distance.

Integrity Management

The passage of the 2002 Pipeline Safety Improvement Act – which required detailed assessments of all pipelines operating at 20% or higher of specified minimum yield strength (SMYS) - is the driver for this research for National Grid. National Grid is funding innovative research in the areas of wall loss sensing for unpiggable pipelines and novel methods to assess the condition of cased pipe. These challenges have resulted in the Integrity Management area being the largest R&D spending area for National Grid. Within the overall category of Integrity Management there are three project areas:

Robotics: In line Inspection (ILI) using smart pigs is considered the most desirable method of pipeline inspection among the three methods (In line inspection, Direct Assessment, Hydrostatic Test) specified by the US DOT's Pipeline and Hazardous Materials Safety Administration (PHMSA), yet many of National Grid's older transmission lines are not piggable. To meet this challenge we participate in the NYSEARCH Robotics program which is developing robotic, self powered sensors for 6" through 36" transmission pipe. These inspection tools are battery powered and are launched "live" into the pipeline and communicate via wireless signal. Pipe wall thickness measurements are either remote field eddy current (RFEC) sensing or magnetic flux leakage (MFL) sensing. The robotics program has received significant support and cofunding from the USDOT and other industry outside NYSEARCH; to date about $8 million has been received from the USDOT alone. The benefits of this technology investment is pipeline safety, ILI, as mentioned, is the most desirable of the three mandated inspection methods, and savings can be considerable, though highly site specific. In this reporting period the Company has funded the following projects:

M2001-014 - Explorer 2026 Robotic Inspection System for Unpiggable Pipelines using Magnetic Flux Leakage (MFL) Sensing. Explorer 2026 is a live entry, battery powered untethered robot designed to enter and inspect transmission pipelines 20 in. through 26 in. diameter at pressures up to 750 psi. Wall loss measurements are by

industry standard MFL sensing. The design of the robot and sensor specifically overcomes the restrictions that cause a pipeline to be designated "unpiggable." These restrictions include short radius or back to back elbows, mitered bends, presence of plug valves (these are valves that do not have a full diameter opening and won't allow a typical pig to pass through) or no/low flow conditions. The robot is launched "live" into a pipeline and travels under its own power along the pipeline taking wall thickness measurements along the way. Explorer 2026 is fully developed and has completed two of three field demonstrations at host LDC sites. It will be in full commercial operation later in 2013.

M2003-009 - Explorer 6/8 (Explorer II) Robotic Inspection System for Unpiggable Pipelines using Remote Field Eddy Current Sensing (RFEC). Explorer 6/8 is a live entry, battery powered, untethered robot designed to enter and inspect 6 in and 8 in diameter pipelines operating at pressures up to 750 psi. Wall loss sensing is through a novel sensor called "Remote Field Eddy Current" (RFEC) sensing. Development of this sensor was itself a separate R&D effort and the sensor represents advancement over state-of-the-art magnetic flux leakage (MFL) sensing. The reason this new sensing technique was developed is that traditional MFL sensing creates high strength magnetic fields and given the small diameter of these pipelines not enough robot power could be developed to overcome these forces and move the robot down the pipeline. The robot is specifically designed to overcome obstacles that traditionally cause a pipeline to be classified unpiggable, such as mitered bends, back to back elbows, and low or no flow conditions. The robot consists of drive modules, steering modules, cameras on front and back, and the RFEC sensing module in the middle. The robot is placed in a specially designed launch tube which is mounted on standard hot tapping equipment affixed to the pipeline. The robot is then launched into the pipeline under live gas conditions and travels down the pipeline under its battery power at about 15-20 feet per minute, collecting wall thickness measurements. After the conclusion of the "pig run," data is analyzed and a report on anomalies found, if any, is made.

An important part of any R&D project is a serious and robust field demonstration phase. For this project, the Company served as a field demo site at its 6 in dia 473 psi gas transmission pipeline in Oneida, NY. During this 3 day demo, the Explorer 6/8 robot scanned over 4900 ft. of this pipeline and found no anomalies. This scan provided the company with added insurance that there is in fact no corrosion defects present in this high pressure gas main. This robot and its supporting technology has been licensed to Pipetel Inc, a robotic inspection services company in Buffalo NY, and is now in full commercial operation.

M2011-006 – Robotics Supporting Technologies. Modifications are being designed that will allow in-line battery recharging (to extend the range), new sensors to detect cracks, and a "rescue tool" that will allow a disabled robot to be retrieved.
In testing conducted to date, battery life is the factor most limiting the range of the robots. It was realized by the company and others that a more efficient way was needed to recharge the batteries than removal of the entire robot from the pipeline. The technology developer, Invodane Engineering Inc. conceived of an innovative method of recharging

the robot via an "in-line" charging system. A charging cable will be inserted through a small tap on the main and the robot can remain in the pipe while being recharged overnight. Based on recent industry pipeline accidents there is increased focus on sensors that can detect cracks. Although less of a threat than corrosion wall loss, crack sensing is the focus of new development efforts. The benefit of this technology is increased assurance of the integrity of the company's transmission system.

A rescue tool" will be developed that will assist in the retrieval of a failed robot. This will give the company greater assurance that the robots can reliably be placed inside its piping network. On some critical pipelines this may be a requirement before the robot is placed in the pipeline. The project is designing, developing and testing additional sensors to add to NYSEARCH's inspection platform for unpiggable mains. Supporting technologies that are being addressed under this project include mechanical damage sensor/ovality sensor, crack sensor, MFL sensor for 6/8, bend sensor, methods for cleaning the pipe at the launch point and ahead of the tool and methods for in-line active charging as well as a rescue tool for the commercial system. We are also developing and testing a hardness test module to add to the Explorer series of robotic platforms for internal testing of material hardness and yield strength.

M2011-009 – Explorer 30/36 Robotic Inspection System for Unpiggable Pipelines using Magnetic Flux Leakage (MFL) Sensing. The Company and two other LDCs are funding Explorer 3036 which addresses larger size transmission piping inspections in 30" through 36" pipelines. This project is still in the development phase and will incorporate all the features of the existing suite of robotic inspection tools such as live launching, plug valve and short radius bend negotiation, all in pipelines up to 750 psi operating pressure.

M2013-001- Explorer 16/18 - Inspection of Unpiggable Pipelines. This Special Project was an Accelerated Development effort cofunded by Invodane to design, manufacture, integrate sensors and supporting technologies and test prior to commercialization.

M2013-002 - RMD Crack Sensor using Eddy Current Technology. RMD has developed a new eddy current sensor that in early studies has shown promise for detecting crack defects. The new sensor is different from existing eddy current sensors in two regards: (a) it uses solid state technology instead of the traditional coils (which have inherent limitations in providing high accuracy and detectability), and (b) it is easily and inexpensively fabricated in inflexible and flexible substrates using mass production techniques. The combination of these two factors results in an inexpensive sensor with resolution and sensitivity superior to traditional eddy current sensors. This project first proved the feasibility of using their EC technology for the detection of cracks in natural gas pipelines and is now advancing to development and testing as well as integration onto the EXP series of robotic platforms.

Cased Piping: Research into cased pipe assessments is an important part of the transmission pipe integrity management program. Transmission piping placed concentrically within a larger "casing" is a common practice when pipelines pass under major highways, railroads or bodies of water. Assessing the condition of these "carrier" pipes within casings can be difficult if the pipeline is not piggable. The company is involved in several research efforts to address this important issue. The efforts consist of software tools to evaluate casings, and inspection hardware to perform inspections. A very promising technology is "Guided Wave," in which an ultrasonic signal is propagated along a pipeline from a remote location revealing flaws in inaccessible areas of the pipeline.

M2001-003 - Cased Pipe Risk Assessment Model. This project involved the construction of a software tool program that prioritizes casings in terms of relative risk. The program considers inputs including, but not limited to corrosion rate, degree of cathodic protection, presence of moisture and wall thickness of the pipe and categorizes casings in terms of probability of failure. Casings with higher risk scores can be scheduled for further follow up inspections while those with lower scores can be monitored. Consequence of failure can also be added to the model, thereby producing a total risk score, which is the product of probability of failure and consequence of failure. Depending on the degree and accuracy of the data that is input into the model, the model can also calculate time to failure in years. A follow on to this project involved lab and field analysis of corrosion rates in various environments. With this information, a corrosion rate can be entered into the model which would be most representative of actual corrosion expected in the field, and not theoretical (overly conservative) rates. This project benefits the company by allowing it to prioritize inspections of riskier casings first and perform remedial actions, if required, on those riskier casings.

M2007-001 - Mini-camera for cased pipe inspections. This is a crawler camera magnetically attached to the casing. It can navigate down the length of the carrier pipe returning video image of the pipe. The camera has been deployed successfully at several sites and a follow on phase to the project will incorporate ultrasonic sensors for wall thickness readings and humidity gauges to assess the presence of moisture (a key ingredient that can accelerate corrosion). The mini-camera does not, by itself, provide a complete assessment of the carrier pipe condition but is rather another "tool in the toolbox" when used with other assessment methods such as Guided Wave technology.

M2007-003 - Multi Technology Validation Testing for Cased Pipe Applications. This is a testing program for various technologies, which may have promise for inspecting wall loss and other defects on carrier pipes within casings. Technologies tested were guided wave, magnetostrictive sensors (an in-situ type of guided wave), the casing camera, and Time Domain Reflectometry (TDR). Some of the technologies tested are commercially available and some are still in the development phase. The results of this test program gave the company valuable information on to the effectiveness of these various inspection techniques. The two most promising are guided wave and the casing inspection camera. The magnetostrictive sensors were not as sensitive as traditional guided wave, and TDR, although promising, will not be seriously pursued at this time. A

new phase of this project has recently been authorized which will focus on more detailed testing of guided wave. All tests are conducted at the NYSEARCH test bed, which is a network of above ground and buried pipe containing machined defects. This is an effective way to compare technologies as all tests are on the same piping components, and defect locations are known only to NYSEARCH staff. However, the company took an additional step and developed a test program for guided wave on its own in-service piping. This project is more fully discussed later in this report.

M2011-007 – Cased Pipe Inspection via Vents. National Grid has had success in its downstate territory with the mini-camera for cased crossings, described above, but the drawback to this technology is the requirement for costly excavations to gain access to the casing annular space at the end seal. An alternate approach is to gain access to the annular space from above ground, through small diameter vent piping which is present on casings. Technology to provide this visual inspection does not exist. The technical approach on this project is to use commercially available camera technology and adapt it to travelling down through the vent piping until it reaches the casing annular space. Through a technology search for new technology providers, NYSEARCH has qualified a small robotics company, Honeybee Robotics, to perform robotics work, and they will perform on this project in a two- phased approach with a go – no/go decision point after Phase 1. Phase 1 will demonstrate the feasibility of adapting existing technology to the task of negotiating the vent piping to gain access to the casing annular space. Such access will be constrained by the small diameter and sharp ninety degree bends that are normally present in casing vent piping. Cleanliness of these vent pipes may also be an issue. If the testing reveals that access to most typical casings can be gained, then the project will proceed to development of a prototype system that can enter the annular space and obtain meaningful information. The benefit is compliance with pipeline integrity management regulations at a significantly lesser cost than traditional means of gaining access to a casing. This project is focused on developing and testing concepts of a compact tethered robotic camera. The successful robotic camera is intended to provide the operator with insight about a cased pipe by gaining access to the annular space through a typical casing vent without requiring excavation.

Other Integrity Management Research

Included here are various projects that contribute to our understanding of, or help us meet, transmission or distribution integrity management requirements.

M2005-003 - Design, Construction & Operation of Regional Test Bed. An above ground and below ground pipe network that has been built specifically for testing new inspection technologies by member gas engineers. This 1200 foot network features different coatings, known anomalies of different sizes, varying soil types, varying welds with good and bad weld practices, different joints and other features for future use on other gas operations purposes. The test bed site is a NYSEARCH/NGA site that is leased from New York State Electric & Gas in upstate New York (Johnson City near Binghamton).

M2007-005 - TransKor Remote Inspection Testing (Magnetic Tomography). The magnetic tomography method (MTM) is a commercial, non-intrusive, above ground method of pipeline inspection developed in Russia by TransKor. Through NYSEARCH, the Company became interested in this technology as an additional "tool in the toolbox" for transmission pipeline assessment. Although other above ground assessment techniques are in use today, they rely primarily on detection of coating failures. MTM measures the inherent magnetic field surrounding a metallic pipeline and detects stress risers in the pipeline by analysis of the pipeline's magnetic field. Stress risers are indicative of wall loss, welds, manufacturing defects, or mechanical damage such as dents or gouges. A test program is underway by the Company and other LDCs who are members of NYSEARCH to thoroughly test the capabilities and accuracy of the MTM. The ultimate goal of the test program is to evaluate the performance of MTM and have it recognized by PHMSA as an "other technology" suitable for transmission pipeline assessment. MTM could provide a significant benefit to the company's Integrity Management plan by providing a much less expensive and more thorough assessment method which requires only a simple walk-over of the transmission pipeline being assessed.

M2009-001 - Holistic Review of Distribution Integrity Management Plan (DIMP) Risk Practices and Models. In 2010 the Pipeline and Hazardous Materials Safety Administration (PHMSA) issued regulations requiring operators of natural gas distribution systems to implement a formal distribution integrity management program. The regulations are not prescriptive and don't require specific types of inspections and assessments as do the transmission integrity regulations, but they require operators to risk rank their distribution system. The Company undertook this project to more fully understand exactly what type of risk modeling may be best suited to analysis of a gas distribution system. Some of the projects' findings suggest that age of the distribution piping alone is not a complete indicator of risk, but other factors such as material type, location, and potential for operator error all factor into a relative risk ranking. Availability of data on the distribution system is also key to developing a reasonable and useful risk model. (For example, although age, material type and location of pipeline segments are certainly known, various component types or specific installation practices are not always known with the same certainty.) Conversely, overloading a risk model with too much specific data does not result in a useful risk tool either.
The final report on the project provides suggestions on a risk management approach and guidelines on making decisions on purchase or development of a specific risk model. The benefit is information and guidance to the company regarding the best method to risk rank its distribution network.

M2012-003 – Enterprise Level Assessment of Data Management Systems. This project addresses a relatively new requirement for gas distribution operations, namely to establish traceability – from initial manufacture to installation – of gas system piping components, and a means to track the location and installation parameters of these components, and integrate this information into existing company data management systems. The best methods of doing this, both from a hardware and software perspective, are being explored in this project. The company is funding this project to gain important

information about this new industry initiative, but because we are conducting active field demonstrations via a similar OTD project (OTD 5.11.m) we will only be observers for this project.

OTD 2.11.d - RSD X-Ray. This non-destructive examination (NDE) method has advantages over traditional X-Ray. For example, radiation levels are reported to be lower, and resolution can potentially be higher. Additionally, images can be displayed in real time. As opposed to traditional X-Ray, which requires through-the-wall penetration from the radiation source to a film on the back side of the weld, RSD X-Ray works on the principle of backscatter, or reflection of the X-Ray signal. The detector can be outside the pipe, co-located with the source. Before such a new technique is adopted it needs to be tested to demonstrate that it is capable of identifying flaws in welds with the same sensitivity and accuracy as traditional X-Ray. GTI will work with the vendor of this equipment to perform blind tests to demonstrate this. The results of the blind tests will indicate whether the project should proceed and whether equipment and techniques should be developed for practical applications in the gas industry. If successful, this method of non-destructive examination (NDE) could also be applied to pipeline integrity assessments of existing transmission pipeline segments via incorporation on to a pipeline pig, or a robotic internal inspection device.

Using Nucsafe's Scatter X-ray Imaging (SXI) technology, the first iteration of this investigation utilized standardized PE disks with precisely measured defects placed in the fusion interface. The objective was to develop a repeatable methodology of introducing specific defects into the fusion interface and to scan a sufficient number of replicates that would allow probability of detection statistics to be calculated. A set of calibration specimens was prepared at GTI and sent to Nucsafe for scanning. The scan results showed that while the disks were detectable the interfaces between the disks and the pipe dominated the signal and masked the included defects in many instances. The initial approach was abandoned in favor of that utilized in OTD Project Number 2.6.e which was more successful.

OTD 4.7.g - Yield Strength Determination. Operators with incomplete records need a better way to determine the yield strength of their pipeline segments if it is unknown. Current regulations require that operators either take a full size cutout of the pipeline and subject it to laboratory testing, or assume a low value of 20,000 psi. Obtaining full size cutouts is disruptive to pipeline operations as it would require a full shutdown of the pipeline. Assuming 20,000 psi could result in the pipeline being in an (assumed) over pressure condition when in fact it may not be. GTI developed a method to determine the yield strength of a pipeline through lab testing of "sub-size" samples. The samples can be obtained easily by using standard hot tapping equipment without shutting down the pipeline. A follow on phase to the project will utilize sophisticated statistical techniques to possibly lower the number of sub-size coupons required for given lengths of pipeline. The benefit to the company is a less expensive and less disruptive method for positive determination of yield strength, should any of the company's records be incomplete.

OTD 4.8.a - Guided Wave Equivalent to Hydrotest. The objective of this project was to perform a validation effort to allow the use of GWUT as an acceptable inspection technique by demonstrating the ability of GWUT to perform equal to, or better than, a hydrotest. The specific objectives of this project were to perform the following: Compile data from GWUT inspections that have been validated by design, ILI, or direct measurement, Demonstrate that GWUT finds defects that would pass a hydrotest (therefore substantiating that GWUT will find all larger defects), and Provide a validated methodology for a new standard. Data collection involved gathering all available and acceptable data from prior GWUT inspections and the associated dig records (defect geometry, pipe diameter, wall thickness and grade). Data was only accepted and reported in this study if the GWUT could be verified through direct inspection. The collected data was used to calculate the failure pressure for rupture using the most conservative federally approved methodology, i.e., ASME B31G for all validated data points. The validation calculations were undertaken to confirm or substantiate the following hypothesis: GWUT misses no defects that would fail a hydrotest, and GWUT misses no defects that were found in the direct examination (i.e., determine the False Call Rate). The percentage wall loss vs. anomaly length diagrams plotted to B31G confirmed that GWUT is equivalent to hydrotesting. The GWUT methodology found all those anomalies that would have been found by the hydrostatic testing and GWUT also found anomalies that were too small to have been detected and would survive in a hydrostatic test to a pressure equivalent to the pipe's Specified Minimum Yield Strength (SMYS).

OTD 4.8.i - Extended Reassessment via Wax Fill of Casings. A proper wax fill of a casing eliminates the threat of external corrosion on the carrier pipe by removing any electrolytes in the annular space between the casing and the carrier pipe and replacing it with a dielectric medium (the wax fill). Although techniques for filling casings with wax are well known, there has been no known technique for validating the effectiveness of the wax fill operation so that assessment intervals could be extended. For this project, corrosion monitoring techniques and techniques to determine the completeness of the initial wax fill operation have been developed. Casings were filled with wax and monitored to determine the extent, if any, of corrosion. To simulate actual field conditions, water was left in some of the test sections prior to filling the annular space with wax as well as through ports made through the casing wall and water forced into created voids. Such testing conditions were extreme. Upon post examination, after 1 year of service, extremely low corrosion growth rates were found, at a much lower rate than would be expected. Longer term testing could provide additional data to verify if the corrosion rate drops, stabilizes or does neither over time. More work would be required to quantify actual corrosion rates over a longer time period

OTD 4.9.a - Leak vs. Rupture Boundary. The current Pipeline Integrity rule requires that all pipelines operating at 20% or higher of the specified minimum yield strength (SMYS) are subject to the more stringent transmission integrity assessments. (20% is thought to be the lower limit of pipeline stress at which pipelines fail by rupture). However, there remained questions as to whether 20% is a realistic lower limit. With the support of the USDOT, investigations of past failures coupled with detailed mathematical modeling can confirm that the 20% limit is overly conservative and a more realistic lower

limit may be 30%. The Company may then elect to designate certain pipeline segments as covered under the new Distribution Integrity Management rules. GTI investigated over 20,000 pipeline failures worldwide and was able to draw conclusions as to the parameters that cause pipes to fail via leakage vs. rupture. Not only yield strength but also diameter, pressure, and toughness are factors that determine whether pipes fail by rupture or leakage. The project results showed that for most modern pipeline materials the leak-rupture boundary is more like 30%. Using the results of the project, operators can – with proper regulatory approval – place their pipeline segments in the appropriate integrity management program. The benefit would be that company resources can be directed to assessing the more vulnerable pipeline segments.

OTD 4.11.f and T 768 (non-Millennium Project) - Understanding Threat Interactions. Part of an operator's Transmission Integrity Management program is a relative risk assessment of the various threats that could impact a pipeline. There are various risk models in use that can quantify the relative risk of pipeline failure via the threats that are present. What is not so well developed is a ranking methodology that accounts for threats that can interact, or occur simultaneously on a pipeline segment. For example, what is the additional risk to a segment if external corrosion occurs on a manufacturing defect, or if earth movement occurs in an area with a defective weld? This project will examine a realistic combination of multiple threats that can reasonably be expected and will calculate the additional risk of failure to a pipe segment due to the presence of these interacting threats. This is timely work since the Company and others have been questioned during safety audits by regulators on their methodology for addressing interactive threats. This benefits the company by allowing the most accurate risk ranking and subsequent assessment of the integrity of those segments. Because this is an important issue the Company funded two parallel projects. The first is a short term effort through NYSEARCH that focuses on (but is not limited to) evaluating interacting threats through the existing Kiefner Model, which many LDCs use today. This effort took far longer than expected but an algorithm is now available (Nov. 2015) for use in determination of the risk associated with interactive pipeline threats. Yearly updates will be made to this model as incident data is reported and updated through the DOT under a 5-year contract with the developer. The second is a longer term more theoretical approach by GTI which could provide more overall flexibility.

OTD 4.12.b – Correlating Pipeline Operation to Potential Crack Initiation and Growth. Based on recent industry events coupled with new or proposed regulations, the gas industry is expected to increase the amount of pressure, or "hydrostatic" testing on existing pipelines. In addition to a standard pressure test (in which the pipeline is pressure tested to 1.5 times its operating pressure) there is the possibility that operators would be required to perform a "spike test" in which the pipeline is raised to 90% of yield strength (which could be significantly higher than a normal hydrostatic pressure test).
Such pressure testing, while having advantages over other integrity assessments, can cause cracks to initiate and/or grow. This has been observed in other industries (boiler tubes) but is not well understood in the gas industry. The Company is aware of the advantages of pressure testing but wants to understand the risks that could present themselves due to pressure and spike testing. GTI will leverage previous work done in

the boiler tube industry to develop a model to predict crack growth due to pressure testing. Validity of the model will be tested by subjecting actual pipe specimens to laboratory pressure cycling which can simulate years of pressure testing and/or pressure excursions in a matter of hours. The deliverable of the project will be a model that will relate historical and planned pipeline operations to potential crack initiation, growth and arrest. This benefits the company by insuring that pressure testing does not degrade the pipe segment being tested, with the associated possibility that the pipe could fail while in service.

OTD 4.13.a - DIMP Consequence Model. The objective of this project was to develop a model that quantifies the consequence of failure for distribution systems and DIMP based factors such as population density, proximity of critical infrastructure and business districts, failure mode based on material properties, gas migration patterns, soil and surface conditions, pressure and potential energy. The deliverable of this project is a DIMP consequence model that operators and software vendors can incorporate into existing risk modeling tools.

OTD 4.13.b - Demonstration of 3D Scanners for Anomaly Assessment. A validated tool that eliminates manual data collection of in-the-ditch anomaly measurements using a pit gauge will improve data quality and increase operational efficiency. Automating the process of measuring anomalies found through ECDA and ILI runs could be achieved through various 3D scanning devices. This project's goals are to validate and demonstrate the performance of 3D scanners for automated in-the-ditch anomaly measurement and assessment of corrosion, dents and gouges. The two 3D scanners that were tested demonstrated the ability to provide more accurate and reliable anomaly assessments compared to manual pit-gauge measurements. Recommendations for further assessment include: 1) Evaluate the cost of the products in relation to the value that they provide in terms of improved data accuracy and reliability and time savings during data collection and management. 2) Ensure that 3D scanners are compliant with federal and state regulations.

OTD - 4.13.c EMAT Sensor for Small Diameter and Unpiggable Pipe. This project goal is to develop a bi-directional electromagnetic acoustic transducer (EMAT) sensor that can be used to assess small diameter and unpiggable pipelines containing reduced diameter fittings and other restricting features. Phase 2 focuses on constructing and testing a field-ready prototype based on the success of the bench-scale prototype sensor developed in Phase 1. This research will enable natural gas pipeline operators to identify defects that are traditionally difficult to find and assess and therefore improve system integrity and public safety. The EMAT sensor will be designed to find and characterize cracks in welds and pipe walls. PHMSA is co-funding phase 2 effort with industry funders of this project.

OTD - 4.13.d.3 - Hydrotest Alternative Ph 3. The third phase of this program is to identify and validate inspection and assessment technologies that are equivalent to a 1.25x Maximum Allowable Operating Pressure (MAOP) hydro-test for Integrity Verification Process (IVP) compliance. Phase 2 created the Finite Element Analysis

(FEA) critical flaw data and collected Probability of Detection (POD) data for Electromagnetic Acoustic Transducer (EMAT) and Acoustic Resonance Technology (ART) sensors. Phase 3 will create the critical flaw curves that will allow a comparison to In-Line Inspection (ILI) tool detection capabilities. The deliverable of Phase 3 will be a tool that operators can potentially use to demonstrate equivalence to a hydrotest for a specific pipe segment. The ability to use internal and/or external inspection tools to perform an integrity assessment as a regulatory acceptable alternative to hydro-testing would ensure the operator of the safety of the pipeline and provide significant cost savings in complying with new regulations. It would also provide operators an integrity assessment solution for those critical pipelines that cannot be taken out of service. Furthermore, hydro-testing may increase risk by introducing water that cannot be removed and may accelerate crack growth for certain susceptible pipeline materials. Acceptable alternative methods to hydrotesting are a critical need.

OTD - 4.14.a Fitting and Component Catalogue for IVP. The goal of this project is to develop a catalogue of legacy fittings and components to assist operators in identifying and characterizing assets to comply with PHMSA's Integrity Verification Process (IVP). The envisioned catalogue will contain pictures, descriptions, strength class ranges, and material and mechanical properties. A catalogue of legacy fittings and their characteristics will assist operators in complying with pending federal regulations, specifically the new IVP requirements. An industry catalogue will reduce the cost of gathering and compiling this information and provide support for strength requirements and assumptions when a fitting can be positively identified. This project has encountered issues with obtaining suitable documentation of data for inclusion in the catalog. Initially critical documentation had been located via the internet (only 2 copies existed) and one copy was ordered but the shipment never arrived. The other copy is not for sale and is owned by Chinese interests. Securing composite catalogs of vendor products and parts from the desired pre-1970 era are actively being worked and GTI is in the process of obtaining a paper copy of a large document from Gulf Publishing via loan that may include useful information. Digitizing and collating the potentially thousands of relevant vendor catalog pages from Gulf documents could ultimately lead to generation of a searchable online tool for LDC use. This effort would likely require significant resources outside the scope and budget of this project.

OTD 4.14.c - Surface Indentation for Material Characterization Correlation of Surface Properties Based on Vintage. There is a need to develop correlation factors to relate surface properties to actual material properties to allow surface indentation techniques to be used for material property validation for pipelines. These correlation factors will be based on pipe vintage by decade. Past research has proven the ability of surface indentation techniques such as stress-strain microprobes and hardness testing to accurately determine material properties of pipes within a localized area, but variations in material properties through the wall are problematic for local interrogation techniques. GTI will develop probabilistic confidence intervals that will allow operators to use surface indentation techniques by applying correlation factors to pipe materials that may have through-wall variability. The ability to characterize material properties, particularly yield strength, of in-service pipelines without taking the line out of service or removing

samples will significantly reduce the cost of complying with existing and pending federal regulations. Backfilling records with material property information such as yield strength and toughness also improves integrity management through system knowledge that allows enhanced modeling and analysis. It is anticipated that the results of this research will facilitate the regulatory approval of stress-strain microprobes and hardness testing to characterize material properties of in-service pipe. It will also empower internal inspection tools (such as PRCI's signature pig under development or TDW's MFL tool that may be able to detect signatures) to use surface readings from the inside of the pipe to be applied to the entire pipe wall.

OTD 5.8.e - Tracking and Traceability. One of the requirements of a Distribution Integrity Management program is to "know your system." But there is no industry standard for manufacturers to mark gas piping and appurtenances with critical manufacturing information nor is there a standard for LDCs to record data when installing permanent additions to their gas systems. On the manufacturing side, date of manufacture and lot number need to be recorded in a standard fashion across industry, and installers need a standard way to record location of the installation and identify the crew doing the work. For this project, GTI and a subcontractor formed a steering committee to identify which commonly used materials should be identified, and what pertinent information should be recorded. The steering committee consisted of manufacturers and LDCs. An ASTM F2897 standard was developed to which capture the results of the Steering Committee's decisions and a bar coding protocol was agreed upon. A future phase of the project will develop methods to record, store, and retrieve, if necessary, data on installed components.

OTD 5.9.j - Gas Distribution Model. With Distribution Integrity Management Program (DIMP) regulations now in place, operators will be developing data collection strategies to ensure compliance. One tool that could help operators in this process is a non-proprietary, industry standard data model for distribution assets and operations. A standard data model, the Pipeline Open Data Standard (PODS) model was developed to assist transmission operators in managing their data and ensuring regulatory compliance. The PODS model is an open, industry-standard data model that has successfully been used for over ten years to reduce the cost of implementing software and improve interoperability for the pipeline industry.

Now with DIMP there is a similar need for an industry-standard data model for distribution assets and operations. Gas Technology Institute (GTI) initiated a program to develop the Gas Distribution Model (GDM) to meet this need with three specific purposes. First, the model will be used as a data exchange function between operator data models and vendor's software products to reduce the need for customization. Second, the model can store both transmission and distribution data and will facilitate vertical data integration. Third, GDM could be used as the primary data model for operators to avoid the need for internally developing a model. The Company engineers and IS personnel felt that such a data model would benefit the business and also would facilitate transition to the new SAP system. The GDM initiative brought together a diverse group of operators, vendors, and industry experts to collaboratively develop a GIS-neutral model

that holds promise to reduce the cost of software implementation and improve interoperability. GDM is a flexible model that will grow and expand with continued use and development.

OTD 5.11.m – Intelligent Utility Installation Process (Asset Tracking and Traceability). This project will develop methodology and suggest field processes for capturing data during new installations. It is a logical follow on to the requirements of recently enacted DIMP regulations which require operators to "know their systems." It also will provide the means to implement the results of the "Tracking and Traceability" project which created an industry standard for manufacturers to mark their products with manufacturing data. A key component of the Intelligent Utility Installation project is to achieve standardization across industry. When this project is implemented the company will benefit by knowing precise attributes of its distribution system and will be able to quickly react to reports of possible defective pipe material or fittings.

OTD 5.15.b - Roadmap for an Enterprise Decision Support System (EDSS). By striking the proper balance between competing influences, operators will maximize business health. There is a growing realization among operators and regulators that ad hoc decision making, based on the latest crisis, is not the optimal method for enterprise management and ultimately system reliability, safety, and efficiency. The objective of this project to develop an Enterprise Decision Support System (EDSS) technology roadmap. The EDSS will allow LDC operators to integrate all data and business knowledge sources into a decision support system that will optimize policies related to: risk mitigation, safety, code compliance, customer satisfaction, environmental stewardship, efficient operations and future growth. It is increasingly necessary to optimize various operational decisions based on predefined rationale coupled with comprehensive knowledge of data/system inputs and a methodical risk analysis. Enterprise decisions and risk analysis that will be supported through this process include repair vs. replace vs. rehabilitate, predictive threat interactions and consequence of failure, risk based prioritization of O&M activities, scenario analysis for various risk mitigation strategies, economic analysis, amongst others. Additionally, new asset-based data streams are continually being developed as directed by distribution and pipeline integrity programs as well as the relative ease in which large volumes of system data can be collected. The EDSS will integrate these disparate data streams into a logical system capable of rationalizing the inputs to enable sound decision making. The deliverable of this project will be a well formulated roadmap that provides guidance on how to realize an EDSS. This roadmap will be used to execute a series of stage-gate linked projects that progressively move us towards the goal of a fully functional EDSS.

Plastic Pipe Research

The bulk of piping added to LDCs' networks each year is medium or high density polyethylene (PE), or plastic pipe. Last year alone, the Company added over 500 miles of such pipe to our system. Working with NYSEARCH and GTI, the Company is involved in several research projects designed to improve our understanding of PE performance and develop new products.

M2000-001 - PE Repair Sleeves for Damaged PE Pipe. As an alternative to squeeze off and cutout of minor defects on PE pipe, the Company and others are developing, through NYSEARCH, repair sleeves to reinforce PE pipe in the area of the butt fusion joint, or along the length of the pipe. During routine operations such as new service additions or main extension, minor damage – not causing leakage - can be noticed on the existing PE pipe that is uncovered. The substandard conditions noticed can be either a scratch or gouge on the pipe itself, or a questionable appearing butt fusion joint. The solution, up to now, is removal of the defective pipe segment. Removal is usually accomplished by first "squeezing off" ahead of and behind the pipe segment in question, then cutting it out and replacing it. As an alternative, the PE repair sleeve can be fitted over the defective area in question and fused on to it. The fitting is designed to withstand line pressures up to 124 psi but will not be installed if an active leak is present. The benefit of this technology is lowered repair costs and improved reliability of PE piping systems by reducing the amount of "squeeze-offs" made. These repairs can also be made without causing an outage, whereas a squeeze-off may require a short outage if the pipe is a one way feed.

M2006-002 – Butt Fusion Integrity. This project examines current butt fusion parameters such as pressure and temperature at the joint interface with an aim towards optimizing them. Through a novel test method, the "whole pipe creep rupture test" several test fusions are made and subject to this laboratory destructive test. This test more accurately simulates stresses that actual in-service pipe experiences, and results of these tests can serve to further refine butt fusion parameters and associated procedures.

M2008-010 – UV Degradation of PE Pipe. The Company wants to understand, through testing, what the real time limit for PE pipe to withstand UV exposure without a harmful effect would be. Current USDOT regulations specify two years but the current version of ASTM D2513 (the industry standard for manufacture and use of PE pipe) specifies an outdoor storage limit of 3 years for medium density PE pipe and 10 years for high density PE pipe. But this current standard has not been accepted by the USDOT, who recognize the previous version which limits outdoor storage to 2 years. This project was undertaken to demonstrate, through testing, that pipe stored outdoors longer than 2 years is still suitable for use. Both non-destructive and destructive tests have demonstrated that pipe stored outdoors for three years is suitable for use. The work now is to present the information to the USDOT and request a rule change. The benefit to the Company will be immediate; National Grid recently discarded over $300,000 worth of PE pipe that exceeded the 2 year requirement.

M2009-008 – Ultrasonic Inspection Device for PE Butt Fusions. The aim of this project is to develop a field instrument to rapidly and easily examine butt fusions in the field, providing on-the-spot assurance of the integrity of a newly made butt fusion joint. A low cost user friendly butt fusion inspection device has been a goal of gas industry research for quite some time. Such a device gives greater assurance of butt fusion quality by allowing "on-the-spot" inspections by field crews or supervisors actually doing the work. The Welding Institute (TWI), located in the UK, is a leader in plastic pipe research and was selected to carry out this work in a phased approach. In the first phase, an

instrument was configured to examine and return information on the presence or absence of flaws in the butt fusion. The next phase of the project is to determine which flaws can be accepted and which will cause the pipe to fail. This is done via destructive testing; fusions with varying degrees of flaws are subjected to testing and a "library" of flaws is developed and flaws are categorized as either "causes failure" or "does not cause failure." Based on similar European technology for metric sizes, the objective is to develop and test a nondestructive tool for examination of butt fusion joints (particularly for use with advanced PE materials). This project has taken advantage of significant research already performed by The Welding Institute (TWI) for the European gas and PE piping industries. Extended long term testing is being performed because the test protocols/data from Europe showed that U.S. failures do not occur as rapidly and to test to failure, different conditions needed to be imparted. The significance of this extensive testing is that NYSEARCH and TWI are developing acceptance criteria for use in a tool that does not require a trained technician. Other phased array NDE tools are either not state-of-the-art OR they require a trained technician. In its final form, the instrument will examine field fusions and compare them to fusions in the "library" and be able to give a simple "good fusion" or "bad fusion" reading. The benefit of this work is greater assurance of the quality of a butt fusion and increased safety and reliability of the gas distribution network.

OTD 5.13.c - PE Pipe Splitting—Technology Evaluations, Enhancements, and Standardization of Tool Kits A research team is evaluating and refining existing PE pipe-splitting equipment and developing guidelines. In October 2015, manufacturers performed various pipe-splitting activities with plastic-pipe-replacement construction techniques. — Researchers are seeking additional field sites for this project.

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Live Inspection, Maintenance and Repair

The Company is always looking to minimize customer downtime or gas main shutdown during routine maintenance activities. The following projects help us meet this goal.

M2001-006 - Development/Testing/Commercialization of Real Time Gas Distribution Sensor Network - Phase I-V. This distribution sensing system is intended to provide network sensor data acquisition, robust wireless communication and encrypted data accessible for pipeline monitoring and assessment. Data from these real-time sensors will include pressure, temperature, humidity, flow volume, and direction. The objective of the program is to complete development and testing to the point where Enetics/Telog can commercialize the technology.

M2008-003 - Evaluation of Rapid Crack Propagation. A study to model and test the existing ISO correlation formulas used to determine rapid crack propagation in PE pipe. Through this project, it has been determined that existing formulas are overly conservative and need to be changed.

M2014-001 - sUAS Technology - Regulatory & Technology Assessment. The objective of the project is to evaluate regulatory issues and technology of small unmanned aerial systems (sUAS) devices as applied to gas industry inspections and

surveys. Further, NYSEARCH has been investigating development of methane leak detection module and control system capable of using at tree-top level for leak survey and methane emissions measurement on a sUAS.

M2014-005 - Critical Valve Operability. The objective of the project is to develop a method of confirming valve position and provide validation of a critical valve operability test.

M2016-001 (Millennium); T-770 and T-776 (non-Millennium) - Cured In-Place Composite Liners projects and Technology Transfer, Demonstration & Post Mortem Testing of Cast Iron & Steel Pipe Lined with Cured-in-place Pipe Liners. The objectives of the project were to: 1) gain understanding and support from regulators using Cured-in-Place Pipe (CIPP) Liners as a rehabilitation technique for cast iron and steel pipe, 2) provide an engineering assessment to advance the understanding of liner/host pipe interaction and demonstrate structural equivalence towards repair/remediation of lined pipe/appurtenances, and 3) validate the effectiveness of CIPP-lined cast iron and steel pipe through examination of past studies & further demonstration and lab testing.

M2016-001 (Millennium) - Chemical Longevity & Post Mortem Slow Thermal Cooling Testing of Field Aged Cured-In-Place Lined (CIPL) Cast Iron and Mechanically Joined Steel Pipe. The primary objective of this proposed Phase II project is to further address regulatory concerns by testing field aged extracted cured-in-place segments as they interact with host steel or cast iron pipe to demonstrate the actual impact of slow thermal cooling and perform chemical aging longevity evaluation tests to (100) years. Six test segments of CIPL pipe, three steel (12”-16” diameter) with a mechanical coupling, and three for cast iron (12”-16” diameter) are proposed to be extracted after years of gas service and will be further tested using a solid foundation of protocols by scientists at Cornell University. The cast iron pipe will be flexed to create a circumferential crack prior to testing. Project goals include: 1) performing thermal testing to simulate actual slow cooling in the field, and, 2) conducting independent tests to examine the chemical longevity of a new CIPL pipe to a (100) year life cycle equivalent, 3) completing a workshop with funding member SME’s and Cornell professional staff on “best practices” for evaluating corrosion and structural limitations of host steel and cast iron pipe segments, and, 4) providing a platform that encourages industry and regulatory dialogue regarding the use of CIPL pipe as an option for the renewal of our aging pipeline infrastructure. This will involve preparing information so that the gas industry sponsors develop a unified approach to addressing levels of host pipe corrosion acceptable for CIPL use in field aged CI or steel pipelines.

OTD 2.11.a - Above Ground Leak Repair Systems Testing. The Company and other LDCs desire to qualify various repair products that are sold for repair of above ground leaks on natural gas piping as a permanent repair system. The application is for above ground meter piping on distribution systems. No use of these products on below ground piping is contemplated. Two available products are being tested. Initial tests will be short term testing to establish the proof, or “burst” pressure of the repair system. These tests

are complete with burst pressures found to be well above (by an order of magnitude) normal operating pressures. Plans for long term testing are now underway.
A successful outcome of this project would be that these repair systems would qualify as a permanent repair thus repairs can be made more inexpensively than a shutdown and rebuild of meter piping, with the associated inconvenience to the customer.

OTD 2.12.e - Selection of Liners Composites for the Rehabilitation of Distribution and Transmission Lines. This project is an evaluation of the use of composite pipes and cured-in-place (CIP) liners in the rehabilitation of gas distribution and high-pressure lines. The replacement and rehabilitation of these pipeline systems in congested, urban areas with very limited right of way space is particularly problematic. This project investigates the trenchless rehabilitation options of these pipes.

OTD 2.13.b - Guidelines for Special Permits for Structural Composite Rehabilitations. The objective of this project is to develop guidelines for submitting special permits to state and federal regulators to request approval to use composite materials for structural pipe rehabilitation. The need for new techniques to repair and replace pipe will continue to increase as infrastructure continues to age. While open trench replacement will be the most cost effective technique for many applications, some situations will require the use of trenchless or alternative techniques that use the host pipe as a conduit for installing a new pipe. Composite materials hold much promise for rehabilitating aging infrastructure, including high pressure pipes. Composite materials can have properties that are superior to steel and can be installed in flexible configurations. Guidelines for submitting special permit requests will reduce the cost and time associated with filing the application. Guidelines will also improve the likelihood of obtaining approval through a special permit by ensuring that permit applications are complete and address the issues that are of interest to state and federal regulators. Other means are being explored for regulatory acceptance, as such; this project is temporarily on hold.

OTD 2.13.c - Long-Term Evaluation of Liners and Composite Pipe Materials.
An engineering assessment was conducted to improve testing methods for predicting the long-term performance of liners and composites used in the rehabilitation of aging gas distribution and transmission lines. The focus was on high-pressure (up to 350 psig) composites and liners installed using trenchless technology. — A Final Report containing guidelines is being prepared.

OTD 2.14.a - Composite Repair Wrap for Polyethylene Systems
Researchers are evaluating a new composite pipe-wrap system for the repair of damaged PE gas pipe. Efforts are under way to establish the correct combination of adhesive and wrapping material. — Repaired specimens are being monitored under long-term hydrostatic pressure testing.

OTD 2.14.b - Steel-Pipe-System Repair Technique
A novel repair method for live leaking steel-infrastructure applications was developed and tested. The method uses a mold, resin, and composite wrap to provide safe,

permanent repairs. The goal is to have the technique applicable to steel couplings, threaded joints, cast-iron bell joints, and service tees. Testing is complete and a patent for the technology was filed. — A Final Report is being prepared. Discussions with potential manufacturers are under way.

Trenchless Technology

The Company's primary research effort in this program area is to find ways to complete maintenance with minimal excavation. These technologies will lower cost and result in less disruption to the customer.

M2010-001 – Service Tee Renewal The purpose of this project is to develop a means to renew a service tee under live conditions without an excavation. Gas mains can be rehabilitated via cured in place lining with minimal excavations. Steel service lines are routinely renewed by inserting plastic tubing, with no need to shut the main down. An alternate process, called "Renu" seals the interior of a steel service line with access gained at the meter. The weak link in this process is the service tee, usually made of carbon steel, which is not routinely replaced during the above mentioned gas main and service rehabilitation projects. The Trenchless Technology Center, retained by NYSEARCH to conduct this research, focused first on an appropriate sealant that would effectively seal the interior of the service tee. Spray coatings, liners, and mechanical seals were investigated. A hybrid mechanical seal concept was judged the best of the three alternatives but significant design challenges existed, mostly related to delivery of the sealing system down the length of the service line to the tee (up to 100 ft in some cases). Because of the uncertainties associated with these approaches the Company and the other funders will request proposals for alternate solutions.

T 773 (non-Millennium) - Trenchless Replacement of Small Diameter Steel Gas Service Lines. The objective of the project is to design, develop and test a new system for extracting small steel services, bare or wrapped in the size range of ¾" – 1 ¼" diameter to replace them with same size or larger size PE pipe. If successful for the smaller steel services, the contractor and cofounder also envisions a Phase II to address steel services with diameters of 1 ½" and larger.

OTD 2.8.e - Structural Liners – Technology Search. Large diameter cast iron mains can be effectively rehabilitated by lining them and Ngrid has been using this technology successfully since 2003. The current approved liner for use on gas systems relies on the structural integrity of the host pipe. For this reason, lining is generally limited to cast iron or protected steel pipelines. If a liner could be developed that had structural properties (meaning it would resist external loads such as traffic loading) more pipelines could be candidates for lining.

Four liner manufacturers who make structural liners for other industries (water) were contacted and their products' capabilities were discussed. One manufacturer seems to have a product that may meet the requirements for gas service and further evaluations will be required. This project would benefit the Company by expanding the available pipelines that could be rehabilitated by lining as opposed to replacement, resulting in lower cost and less disruption to the community and customers.

OTD 5.10.f – Cold Assisted Pipe Splitting One of the methods to renew deteriorated steel pipe is to split it by pulling a tool with cutters through it. A new length of PE pipe is attached to the rear of the cutter. When the cutter emerges from the pipe, the new length of PE pipe remains as the new gas carrier. This can be a cost effective rehabilitation method but many times the splitting operation is difficult because of the ductility of steel pipe. This project investigated whether liquid nitrogen or some other cryogenic liquid could lower the temperature of a steel pipeline to a level at which the pipe would transition into the "brittle" zone and be easier to split.
GTI Engineers determined that the quantities of cryogenic liquid required would be excessive, and further found that during testing; the cooling effect was not uniform through the length of the pipe. Since the project had reached a go / no-go milestone the Company decided not to continue further funding.

Gas Quality

The gas supply picture for the Company's service territory – and indeed for much of the nation – is evolving, and unconventional supplies such as LNG, shale gas, biogas, and gas from other geographic regions will soon be a part of our supply picture. While research into supply itself is outside the scope of the Millennium funding mechanism, the effect that these diverse supplies may have on our existing infrastructure is a new and growing R&D area for us.

M2005-005 – Gas Interchangeability for Installed Components A multi-phase study investigating LDC coupling components and associated materials and whether varying gas compositions in a range of temperatures and pressures can create leakage in the couplings. This project studies the effect that a wide range of future expected gas supplies from non-traditional sources may have on installed infrastructure components such as gaskets, O-rings, seals, and diaphragms. Anecdotal evidence exists that suggests that gas supplies outside of normal expected limits may have been the cause of component failure in two east coast LDC distribution systems, but no definite conclusions can be reached, and no similar studies have ever been undertaken. This test program is designed to determine, through controlled laboratory testing at GTI test facilities, whether gas composition changes affect the performance of elastomer components mentioned above. Baseline and test gasses were agreed upon and procured, and infrastructure components were removed from the field and sent to the GTI lab for testing. Components are cycled through a "baseline" gas (the gas normally expected) and then cycled through several "test" gases (representing future expected supplies). During this cycling, pressure and temperature are also varied. The results of this test program will allow the Company to take action by removing and replacing components determined to be "at risk" or set new supply tariff limits with a scientific basis for setting them.

M2011-002 - Storage Effects on Gas Quality - A portion of the gas entering the Company's system comes from underground storage in geological formations. There is anecdotal evidence that gas leaving storage can have different properties than gas entering storage, for several reasons. These reasons can include presence of water or other substances in the storage formation, temperature variations in the formation (which

could affect dew point), blending (or lack of blending) and others. None of this is well understood or modeled. The Company would like to understand this better from the perspective of the ultimate effect on our distribution system. This would help us better negotiate tariffs for gas delivered that would not have harmful effects on pipe materials as well as gaskets, seals and diaphragms. NYSEARCH commissioned a subcontractor for a two phase effort; the first phase is a literature search which will identify the key parameters that affect gas quality in storage. Assuming a successful outcome of the first phase, a second phase would develop a predictive model so that ultimate gas qualities can be more accurately projected. This benefits the company by enabling it to better predict quality, set tariff limits that recognize the potential for change in the quality of the gas in storage, and ultimately insure the integrity of our infrastructure.

M2011-003 – Odor Masking. Odor Masking is a phenomenon recently observed in gas distribution systems in which the odorant, although present in the required concentrations, is not perceptible to the human sense of smell. It is manifested by no odor or a markedly different odor than is usually associated with natural gas. This is different from Odor Fade, in which the concentration of odorant is lowered due to its being absorbed by the pipe (common in new piping systems) or by trace constituents in the gas stream. The Company is concerned about this issue because absence of the characteristic gas odor will prevent recognition of gas leaks or other hazardous situations.
Odor Masking is not well understood but the Company and other NYSEARCH members are working with Cardiff University in the UK and a professor there who has done some research in this area.

It is known that pairs of compounds, called "antagonistic pairs" can act together to change the perception or intensity of an odor and that this reaction actually occurs in the human nose or brain. In Phase I of this project, researchers at Cardiff University have demonstrated that certain chemicals that can be present in a natural gas stream can mask the odor of some sulfur compounds that are commonly used in odorant. This was shown by actual tests involving volunteers at the university who ranked the intensity and pleasantness of these chemicals before and after mixing. The Phase 1 work will attempt to identify as many of these antagonistic pairs as possible. In Phase II, just beginning now, researchers will attempt to identify where this human response is taking place. This is important because it will lead to certain mitigative strategies depending on where the response takes place.

The ultimate goal and benefit of the project is a practical pipeline operator guideline on how best to mitigate this phenomenon. For example, the guideline could call for tariff limits on certain trace constituents be set at a lower level, or it could recommend the use of certain odorant types that are more resistant to masking. A successful project outcome would eliminate the situation where a gas leak goes undetected with potentially catastrophic results, such as the Texas school explosion in 1937. The project identified the causes and mechanisms associated with a phenomena that is not fully understood, odor masking. The overall goal was to develop guidelines to mitigate odor masking and anticipate issues that arise from variations in gas quality. While the mechanisms were

identified and confirmed, the program did not move to distinct measures for mitigation due to results that unveiled more issues to resolve in terms of human variability in terms of concentration sensitivity. Status is "Complete" until parallel work determines need

M2013-003 - WKU Advanced Chemical Sensor. Through the TecFusion/Oracle program, NYSEARCH identified the smart nose technology of Western Kentucky University (WKU). This technology uses nanosensors to develop a smart nose that is rather sensitive and can be used to also detect a certain gas signature. The Western Kentucky University (WKU) project first completed a feasibility study for using an "artificial nose" system to detect a series of analytes of interest to the natural gas industry. The nanosensor technology leads itself very well to small, low power instruments, ideal for field deployment. This project is now advanced to development and testing of advanced prototypes.

OTD 7.8.a – Pipeline Quality Biomethane: Guidance Document for Landfill and Water Treatment Conversion. This is a national study and sampling program to determine acceptable gas quality for introduction of landfill and wastewater-derived biomethane into Ngrid's distribution system. No such standard exists in the US today. Information was assembled on landfill and wastewater biogas production, treatment, gas quality standards, and test protocols surrounding biogas production and use. A lab test program was executed testing raw and processed biogas samples for over 400 chemical species. A guidance document was prepared for safe interchangeable use of landfill and wastewater treatment biomethane in LDC networks. The results of this project show that these biomethane sources can be safely introduced into LDC networks.

OTD 7.9.c – Assessing Acceptable Siloxane Concentrations in Biomethane
Siloxanes are a class of compounds that are silica-based and found in many personal hygiene and health care products. As such, they enter waste streams and can be found in biomethane produced from landfill or wastewater biogas cleanup systems. There is evidence that siloxanes, when combusted, can result in excessive deposits of silicon dioxide on boiler tubes or gas turbine blades. The Company is also concerned because the effect of siloxane on standard infrastructure components is unknown. GTI is assessing industry data and attempting to determine what levels of siloxanes in biomethane would lead to issues with end use equipment or pose indoor air quality issues. In addition to the acceptable concentration of siloxane, other unknowns must be understood, such as where, and at what ratio, the biomethane enters the LDCs' distribution systems, and what flows and velocities can occur at the end use equipment. This project fills an important knowledge gap and allows the company to prepare for the introduction of another non-traditional supply into our existing infrastructure.

OTD 7.10.a – Trace Constituents in Natural Gas. Significant research to identify the complete range of trace constituents in natural gas has not taken place in 20 years. In that time span, non-conventional supplies are entering LDC systems and these supplies are expected to have trace constituents in them. The objective of this project is to build a database of trace constituents specific to current supplies of gas flowing into LDC

systems. The Company will use this database to assess new gas supplies from unconventional sources such as shale gas to see whether these new supplies are compatible with existing supplies. Routine analysis of natural gas supplies is an established practice. Heating value, specific gravity, hydrocarbon content, and some inerts such as nitrogen are measured periodically, but trace constituent analysis is not routinely done. A partial list of trace constituents of concern would include halocarbons, volatile organic compounds (VOCs), siloxanes, ammonia, trace metals, and bacteria. Comprehensive knowledge of the presence and amount of these constituents would allow intelligence to be placed on setting limits for these constituents in future supplies.

OTD 7.10.b - Odor Fade. Odorants used in the gas industry in North America all contain sulfur, carbon, and hydrogen and belong to a category of chemicals known as organosulfurs. The most common odorants used are alkyl mercaptans such as t-butyl mercaptan, alkyl sulfides such as dimethyl sulfide (added to lower the freezing point of the mixture), and tetrahydrothiophene (a cyclic odorant). This project was designed to investigate causes of odor fade in natural gas distribution systems. A preliminary literature survey reviewed the availability of current and historical data. It concluded that the primary causes of odorant fading include: 1) surface interactions of odorants with different pipe materials, 2) scrubbing or dissolution by condensates or cleaning fluids, 3) chemical reaction/oxidation of odorant with other components in the gas stream, and 4) other system state variables. Thermodynamic prescreening was one tool used to look at the possible reactions involving more common blend stock odorants. In addition to forming (mainly) disulfides and iron sulfides, mercaptans might also decompose or react with trace gas processing constituents (e.g., methanol). Analysis of data collected by funders over the study period indicated that: most odor fade events were reported to have been prompted by weak sniff test results and most respondents reported performing follow-up quantitative analyses. No instances of solvent odors were reported. Two odor fade events were reported with plastic (PE) pipe, the others with steel pipe. Ambient temperature ranged from 20-90°F. All events involved a single source of natural gas. No pipe cleaning was mentioned as having been employed by any of the respondents. Odorants involved were t-butyl mercaptan mixtures with either dimethyl sulfide, i-propyl mercaptan, or tetrahydrothiophene; no odorizer operational issues were noted. Supplementary odorant injection was employed to increase odorant levels by all but one of the respondents. Findings include: analysis of TBM loss in plastic pipe with respect to temperatures. THT loss with respect to temperature, TBM reactivity with steel pipe vs. plastic pipe material, and steel pipe and odorant levels of TBM and THT in relation to presence of rust. When water was introduced into the steel reactor, the rate of loss increased further. Water by itself had no effect (as seen in the inerted reactor tests), but had a significant effect when iron was present. Initial modeling of the 1-step versus multi-step reaction mechanism showed the multistep mechanism to be more robust. The information gained in this project was used to prepare a suggested revision to Chapter 7 of the current edition of the AGA Odorization Manual, last revised in 2000. This study was completed end of 2014

OTD 7.11.a – Gas Quality Resource Center. The Gas Quality Resource Center is intended to provide technical support necessary to identify and fill knowledge gaps

regarding potential industry issues associated with changes in gas composition profiles in North America. The Resource Center will provide a centralized "clearing house" for information related to gas quality, analysis of current flowing gas supplies in North America, identification of constituent trends across identified regions, analysis of current technical regulatory trends associated with pipeline tariff negotiations and identification of research needed to help fill information gaps ultimately aimed at maximizing supplies while balancing the needs of pipeline integrity and end use concerns. The resource center would maintain information on gas compositions and pipeline tariffs, and would serve to identify and launch research as appropriate related to gas quality issues. Issues such as odor masking or siloxane levels are examples of the types of research that could result from the Company's participation in the Gas Quality Resource Center.

OTD 7.11.b – Trace Constituents Sensors This project will identify candidate sensors or sensor technologies for measuring, perhaps in real-time, trace constituents in new gas supplies, such as landfill gas, biomethane derived from a variety of biomass sources, and unconventional supplies such as shales, tight sands and coal bed methane. The Company is aware that its future fuel mix will include renewable and unconventional gas. The need to understand the composition of a new gas supply and to monitor its components is increasing as the number and variety of sources grows along with their frequency of introduction into the natural gas pipeline network. The project will proceed on a phased approach, future supplies must be identified, and constituents of concern present in these supplies also need to be identified. For some new supplies such as landfill gas, research into gas trace constituents had already taken place, for others for example shale gas, less information exists. Once the constituents have been identified, instruments that can sense these constituents will be identified and assessed. The benefit of this work is the ability to monitor the composition of new gas supplies and the associated capability of protecting our distribution assets.

OTD 7.15.a - Real-Time Gas Quality Sensor. The introduction of shale gas and upgraded biogas into the gas transmission network is increasing the importance of accurate and regular monitoring of the natural gas heating value and composition. Currently used gas chromatographs (GC) are expensive and slow. The project objective is to demonstrate development of a practical, reliable, and real-time gas quality sensor (GQS) that can detect changes in gas quality (heating value, and concentrations of methane, ethane, propane, butane and carbon dioxide concentrations) in real time and can provide this data to the operators of an LNG plant or other facility.

Environment

Projects in this area are focused on new technologies to more easily and cost effectively remediate MGP sites. A more recent focus in the Environment area is related to Climate Change Concerns.

M2001-002 – Management of Impacted Sediments. The company formed and led this project, which was funded by other NYSEARCH members as well as a national consortium of industry and the US Navy. This project studied the correlation between polycyclic aromatic hydrocarbon (PAH) concentrations in manufactured gas plant (MGP) sites and the actual bioavailability of these compounds to living organisms, with the goal

being more realistic guidelines for site remediation. Not all PAHs at MGP sites are actually bioavailable, and therefore harmful, to organisms and the environment. This project developed a new analytical method to determine actual bioavailability. Benefits include the potential of a greatly reduced remediation area. A final report has been submitted and accepted by the project funders as well as the USEPA, the NY State DEC and the NY State Department of Health. In February 2012 the NY State DEC issued a remedy decision based on the new analytical method for the city of Hudson NY (Water Street) company site. Savings realized for this one remediation are approximately $26M.

M2008-006 – Expanding the function of No Blow Tools. Tools to make "live" taps into gas mains are commercially available but during certain operations small amounts of blowing, or escaping gas are present. A set of innovative tooling was developed to enable plug insertion or removal, or insertion of stoppers. This benefits the environment by reducing the amount of methane (a greenhouse gas 21 times more potent than carbon dioxide) released into the atmosphere, and also contributes to worker safety. A second phase of the project developed an innovative method to reinject gas into an adjacent main segment rather than blow it off to atmosphere during a special test called a "flow test." This method reduced greenhouse gas emissions and lessens customer concerns and complaints.

M2009-003 – Adaptation to Climate Change. The company and others recognize that there are two aspects to climate change, how we, through our methane and CO2 emissions, affect climate change, and how we, as LDCs, adapt to climate change effects and impacts that are certain to occur in the future. To meet this latter goal the Company and others commissioned a study that investigated a range of future climate models, predicted maximum and average expected temperatures and sea level rise, and developed a framework for estimating risk and remedial action to address those climate changes. Phase II examined more detailed flood risks at the local level for sponsoring companies. The benefits of this project will be the development of a gas-industry specific risk-based framework for addressing the impacts of climate change on a broad geographic level to give LDCs quantitative information on which climate effects and impacts to focus on and which portions of our natural gas infrastructure are most susceptible to those climate impacts. A final report has been issued and sea level rise has been identified as the main threat to a natural gas distribution system.

M2010-002/ T 776 – Methane MR Sensor/Residential Methane Sensor Pilot Testing Program. See details under Leak Detection and Methane Emission section of this report.
M2010-004 – Soil Vapor Intrusion The work in this project involves characterizing manufactured gas plant (MGP) coal tar vapors so that volatile organic compounds (VOCs) can be conclusively identified as either coming from an MGP or from some other source. For example, benzene, a constituent in coal tar, could also be present in a dwelling from common household sources. If compounds such as benzene are identified near a dwelling, current regulations require extensive sub-slab (below the basement or slab of a dwelling) sampling at a cost of $10,000 per dwelling. However, if MGP coal tar can be ruled out as the source of the contamination, less expensive investigations would be warranted.

M2011-004 – Carbon Calculator. The Company has been voluntarily reporting fugitive methane emissions since the mid-nineties and is committed to reducing its carbon footprint. One component of that carbon footprint is carbon dioxide emissions resulting from normal construction activities. The intent of this project is to quantify the emission reduction that would result from choosing a less energy intensive method of construction. For example, there are two alternatives to installing a new gas main. The first is traditional open trench, where a trench 18 in wide by 3 ft deep is excavated along the proposed length of the installation. In an alternate method, the pipe may be installed via directional drilling. This latter method is quicker, uses less equipment for a shorter time, and eliminates the bulk of new paving that must be applied. But up until now there has been no way to quantify the reduction in emissions. This project involves quantifying the emissions that result from each step of the construction process.

NYSEARCH, together with the North American Society for Trenchless Technology (NASTT) is working with ETA/Environ, to develop the spreadsheet tool. In the first phase of the project, subject matter experts from the participating companies are quantifying types and time on the jobsite of various pieces of construction equipment used on various construction activities. Then, ETA/Environ will use the latest EPA "non-road" emission factors to compile emission rates for the various pieces of equipment. In the final step, ETA/Environ will create a robust, user friendly spreadsheet tool to enable gas company managers to compare the carbon impact of alternative constriction practices.

There are several benefits from this project; determining the construction methods with the least environmental impact, validating the additional (environmental) benefit to public authorities who may be skeptical about the use of a newer or non-traditional construction technique; and it could allow the Company to be proactive in tracking and reporting (if required) these emissions.

OTD 6.8.a - Carbon Management Information Center.
The Carbon Management Information Center (CMIC) was established in 2007 to serve as an on-line clearinghouse for relevant carbon management information. The CMIC serves the gas industry, its customers, and other stakeholders by developing resources and analytical tools to provide clear, concise, and technically-sound information on issues related to reducing the nation's energy consumption, source energy codes and standards, and carbon emissions.

OTD 7.9.d and 7.10.c – Improving Methane Emission Estimates for Natural Gas Distribution Companies. The Company and other LDCs have been voluntarily reporting fugitive methane emissions from their distribution systems under the US Environmental Protection Agency (EPA) "Star" Program since the 1990s. With the recent passage of EPA "Subpart W" LDCs are now required to report these emissions.
To report emissions from its piping network, which account for over 80% of the Company's fugitive emissions from its gas distribution system, the EPA allows the use of emissions factors, expressed in terms of cubic feet of methane per mile of pipe per year.

Different pipe materials have different emissions factors. The factor is simply applied to the mileage of pipe in the system and total emissions are reported.

These emissions factors were developed in the early nineties via a testing and measurement program sponsored by the USEPA and conducted by the Gas Research Institute and subcontractors. The factors have never been updated and the Company and industry in general, are aware that the factor for plastic (PE) pipe is unrealistically high. For example, a similar study in the UK conducted in the early 2000s resulted in a leakage factor for PE pipe that is one half the value used in the US. PE piping systems are fabricated with improved materials and installed under better quality control than in the nineties, and the emissions testing program for PE pipe done then only contained six data points – for the entire nation!

Working through GTI and subcontractors, and with the knowledge of the USEPA, the Company and others are replicating the test methods from the previous study and attempting to develop a more realistic emission factor. Project funders (there are 18 LDCs participating) are identifying leaks in the field and the GTI team measures them. In parallel with conducting the leakage measurement (which involves exposing the leaking pipe segment) an alternate measurement technique is being applied which involves only surface measurement of leakage. If the two separate techniques agree, more field measurements can be taken with the less expensive surface measurement technique. Several field tests have taken place so far with others scheduled. After the PE leakage factor is revised, a second phase of this project will revise the factors for cast iron and bare steel pipe materials. The benefit of this project is more accurate reporting and a better representation of the company's contribution to greenhouse gas emissions.

Infrastructure Support

The following projects benefit overall company operations in areas such as safety, sensing and measurement, advanced material research, community and customer concerns, and general operations improvements.

M2009-002 - Mercaptan Sensor Development. To insure proper odorant levels in natural gas, LDCs are required to perform a periodic "sniff test." The human nose can detect odorant levels in the ppb range and if the gas is properly odorized this provides adequate warning to the public that gas is present at levels well below the "lower explosive limit" (LEL). However, sniffing by humans is subjective and technicians performing these tests can sometimes be desensitized to the odor of mercaptan. Also, the recently identified phenomenon called "odor masking" can cause the characteristic odor of mercaptan to change or disappear. This project aims to develop a portable sensor that can detect mercaptan in the ppb range. It would not replace the sniff test – which is required by code – but would supplement those tests, and would also be installed in areas where odor fade or masking is suspected, to verify that proper odorant levels are present. The technical approach is a unique combination of standard gas chromatography and a relatively new technology called differential mass spectroscopy. This technology was discovered via the NYSEARCH "Oracle" project mentioned above. Feasibility testing

has been successfully completed and a prototype instrument is being built. Due to an instability issue, re-design work was attempted by the first contractor in place of additional field tests. With that work not solving the problem, NYSEARCH sought additional expertise and is now working with UC Davis to resolve the engineering issue associated with instability before going to advanced prototyping and testing. The benefit is advanced warning of possible odorant deficiencies.

M2010-002/T-776 – Methane MR Sensor. See details under Leak Detection and Methane Emission section of this report.

M2010-003 – PCB Absorption in PE Piping. Every year the Company discards quantities of polyethylene (PE) pipe that have been removed from service because they have been damaged by third parties, or for other miscellaneous reasons. The Company ships such pipe to a special landfill that accepts PCB-contaminated pipe because there is no EPA-approved method for decontaminating PE pipe potentially exposed to PCBs. The Company determined that the same approved procedures used to clean and decontaminate steel pipe may be applicable to PE pipe, if it can be proven that PCBs are not absorbed into the wall of PE pipe. Such testing has never been conducted for PE pipe. This is a Material Science Study to evaluate whether there are particular PE pipe characteristics that interact with PCBs. Address decontamination issues so that abandoned PE pipe can potentially be left in place. The Company, through NYSEARCH, engaged Jana Labs – a respected plastic pipe research and testing laboratory – to conduct this testing. The tests are underway with Jana. Pending a successful outcome of the test program, the Company will work with the USEPA to create a standard for cleaning and decontaminating PE pipe so it may be discarded in a normal fashion.

M2011-001 – Self Healing Pipe. Through the NYSEARCH "Oracle" Program, the Company has become aware of advances in material science through nanotechnology. Several concepts related to advanced materials were addressed and the two most promising were self locating pipe (pipe containing materials that would respond to conventional above ground locators, thereby solving the problem of broken or malfunctioning tracer wire) and self healing pipe. (Self locating pipe was discussed among NYSEARCH members and the group, after careful consideration, decided not to pursue that technology at this time.) The Company and other NYSEARCH members want to explore further the concept of self healing pipe so this project was authorized. Our investigations indicated that the addition of different types of nanoparticles into polyethylene (PE) material can enhance its mechanical or electrical properties. One type of adder can actually induce self-healing capabilities in the base PE material. A crack in the material will release a bonding agent and lab experiments conducted by others show recovery of up to 75% of tensile strength of the base material. The Company wants to pursue this further and feasibility discussions with manufacturers will commence. This is a long term project with ultimate benefits realized perhaps 25 years into the future. The project will be carefully monitored and will proceed in phases. Reduction in distribution pipeline incidents due to damage is the benefit of this research. The objective of the program is to develop a new generation of PE based pipes with self-healing properties for use in the natural gas industry. Following completion of the feasibility study, additional

work was completed to prove that the PE pipe when altered for the self-healing nanomaterial would retain its required strength properties and at those conditions, still provide self-healing capability. It has been proved that the strength properties are maintained. Additional research is necessary as to evaluation of all conditions and development of various PE piping appurtenances. NYSEARCH is reframing the program to move from feasibility testing to more advanced development.

OTD 1.12.b - Cross-Bores Detection Using Mechanical Spring Attachment. Research is under way to develop a tool that will detect a hit to a sewer pipe during the installation of a gas pipe. A prototype for field testing was built that uses a mechanical spring system that is activated inside the sewer pipe void to provide a real-time alarm identifying a hit. Laboratory and field tests were conducted in 2013-2014 and a patent application for the technology was filed. In testing, the tool was able to successfully indicate the voids in pipes which were hit (i.e., providing positive indications). Several modifications of the proto-type may be performed with future commercializers. — A report on the results of field-test activities is being prepared.

OTD 1.13.a - Real-Time, Multiple Utility Detection During Pipe Installation Using HDD Systems. Research and testing is being conducted on an acoustic-based technology to detect obstacles during horizontal directional drilling (HDD) operations. The ultimate goal is to develop a system that can automatically and rapidly detect buried pipes/obstacles in front of and adjacent to the drill-head of HDD machines. The system was tested with seismic/noise sources and under differing attack angles to pipes. Post-processing data showed that the acoustic system was able to achieve the average pipe detection accuracy of ± 2.1' during the trials. — New and improved noise sources are being developed for further evaluation.

OTD 1.14.e - Plastic Pipe Locating—Alternatives to Traditional Tracer Wire. OTD along with GTI and 3M submitted a White Paper to DOE/PHMSA for a project that would have a very similar work scope as this current OTD project. The proposal resulted in an award from PHMSA with work expected to begin in the fourth quarter. The revised scope of the project is to develop an electronic marking system that will provide locatability on various-diameter HDPE and MDPE pipes. The project will also assess the technology capabilities versus pipe diameter, burial depth, and pipe-burial methods (horizontal directional drilling, open trench, etc.) —The contract for the new PHMSA-supported project is being finalized.

OTD 1.15.a - Cross Bores—Sewer System Cleanout Safeguard Device. This project focuses on the development of a safety device that provides the ability to seal the sewer-system cleanout opening in the event a natural gas line (inadvertently installed in a sewer) is struck by a power auger or other mechanical tool. The project team finalized a prototype cap design. Based on evaluations, 35 split caps were manufactured and shipped to sponsors for evaluation. — The project team has been in discussions with a manufacturer regarding commercialization of the split-cap safety device.

OTD 1.15.d - Improved Camera Imaging to Identify Cross Bores. The objective of this project is to provide an evaluation of imaging systems with the potential to work in conjunction with various types of trenchless pipe-installation technologies (including the use of horizontal directional drilling equipment with drilling mud) and still be able to positively identify a cross bore. An initial patent/literature search produced no new information on sewer camera technology. This, along with discussions with experts in the industry, indicated that there is little that can be done to improve this technology without additional technology platforms. Subsequently, several potential alternative platforms were identified. — Communications are being arranged with project sponsors to discuss the technologies identified and deter-mine future plans.

OTD 2.7.d - Cold Adhesive Repair and Joining of Polyethylene Pipes with Minimal Surface Preparation. In this project, researchers tested a cold-adhesive repair technique in an effort to develop an economical, reliable, and safe technology to quickly and effectively repair damaged plastic gas pipes. Long-term test results of PE pipes patched with the repair method found that the patching system can be effective. Testing also resulted in additional information about the effective application of the adhesive. — A Final Report on the project is being prepared.

OTD 2.10.b - In-Service Field Evaluation of Polyurea Coating Systems.
As a follow-up to a previous project, research into field-applied polyurea coatings for gas industry use is being conducted on promising coatings. Long-term field trials will be performed to evaluate these coatings and determine a cost-effective coating-application method and process for structural liners. — Installation and evaluation of the coating was successfully completed at a sponsor site in November 2015.

OTD 2.11.a - Development of a System for Repair of Aboveground Leaks.
Researchers are conducting a thorough evaluation of repair methods for leaks on aboveground piping in an effort to establish a basis for choosing the right repair method for a specific leak, establishing levels of adequate preparation, and providing the proper installation for increased reliability. Prototype test samples were constructed to simulate aboveground leaks from varying levels of corrosion (pin holes) and from threaded joints. Test samples were fabricated, fitted with the corresponding repair systems, and hydrostatically tested to failure. — Testing is ongoing.

OTD 2.12.a - Integrated Expert Monitoring and Training System for Butt Fusion.
A set of critical fusion variables is being developed to provide an integrated technology package for use in pipe-fusion training and field operations. The goal is to produce a system capable of flagging marginal fusions in all operating conditions. In the third quarter of 2015, all butt-fusions and low-temperature high-speed tensile tests were completed and creep testing initiated. A significant amount of test data post-processing was completed and correlation of the test data to butt-fusion conditions initiated. — A Final Report is being prepared.

OTD 2.14.c - Assessment of Squeeze-Off Location for Small-Diameter Polyethylene (PE) Pipe and Tubing. Researchers developed a model for predicting the effects of squeeze-off on small-diameter PE pipes. Mechanical testing was tailored specifically for the squeeze-off mod-el to capture the application's conditions. Technicians prepared a total of 230 specimens for testing. The results from the squeeze-off FEA model indicate that a squeeze-off can be performed at a distance three pipe diameters from a fitting with any size pipe. The project team initiated efforts to revise ASTM F1041; however, feedback received from ASTM indicates the project needs to address squeeze-off near mechanical fittings as well. This additional scope of work is to be submitted to the project sponsors for consideration.

OTD 2.14.e - Guidelines/Best Practices for Scraping PE Pipe and Fittings
Research is focused on the development of a functional set of improved, up-to-date guidelines for PE pipe and fittings that take into account current tooling and practices (e.g., scraping) while addressing the variables associated with fusion execution. Information from survey results was combined with data from previous projects and a test matrix for the pertinent tools was developed.

OTD 3.8.a - Addressing Jackhammer Noise Abatement. In urban areas of the Company's territory there is increasing pressure from city officials to lower the noise of commonly used construction equipment. Evening and weekend work, such as is required for emergency response work, only amplifies this need. Pneumatic jackhammers are among the noisiest of commonly used construction equipment. National Grid, in New York City, experimented with insulated fabric jackets that are placed around the jackhammer and while these helped to reduce noise levels, a more permanent solution is desired. The Company and others are working through GTI to try to engage jackhammer manufacturers to examine the design of a typical jackhammer to see if there is any opportunity to reduce the noise produced. It is recognized that noise from a jackhammer is produced from three distinct sources, the internal piston operating inside the cylinder, the air exhaust, and the bit striking the pavement.

The objective of the project is to engage manufacturers and determine whether they are open to a basic redesign effort of their tools to make them less noisy. GTI identified several manufacturers but only one was willing to attend a meeting to discuss the intent of the project. As a result, the project will most likely not proceed to Phase 2, which would have involved detailed noise analysis and would have served as the basis for a redesigned jackhammer.

OTD 3.14.a - MBW Soil Compaction Survey Enhancements. The SCS fills a need to verify soil compaction levels during field operations (excavation back-filling). The memory media that was used in the previous version of the SCS is cumbersome to use and has become obsolete. The industry practices in field data collection have also evolved considerably since the SCS was first introduced. The objective of this project is to upgrade the capabilities of the Soil Compaction Supervisor (SCS) to make it compatible with modern Geographic Information System (GIS) data capture practices as well as more user friendly through better data logging and reporting capabilities. Initial efforts

will also be investigated to determine the SCS's ability to be correlated to a standard proctor value or range. The ability to attach metadata such as GPS coordinates and photos to compaction data is now wanted for entry into a GIS. Transferring compaction data from a mobile device to a GIS with the additional capabilities available on mobile devices (GPS, camera, etc.) will be incorporated into the data acquisition for the compaction record. By redesigning the SCS, a useful tool will continue to be available and the data generated can be directly imported into utility GIS or other data systems. Capturing and archiving the soil compaction data will help ensure that compaction is being performed properly (quality control) and will enable a utility to validate proper compaction to jurisdictional and/or regulatory authorities. The testing portion of the project seeks to better understand the correlation of the SCS data with that from a nuclear densitometer to provide a lower cost alternative.

OTD 3.14.b - Update ASTM Standard of DCP Compaction Control. Through this project, interactions were made with ASTM to update its current standard on the five-pound Dynamic Cone Penetrometer (DCP) compaction control device. The ASTM standard D7380-08 (Test Method for Soil Compaction Determination at Shallow Depths Using 5- lb. DCP), which was developed in an earlier OTD project, completed the balloting process of its standards in September 2015. The OTD-developed standard passed both the sub-committee ballots with no negatives. —The project team is following up with the ASTM Publications Committee to complete the process of adding the new version to the ASTM 2016 standards publication.

OTD 5.6.e – Portable Propane Air Temporary Residential Supply, Phase II
Many routine gas operations require temporary disruption of service to customers. Replacement of aging gas mains requires a brief interruption while the service is transferred from the old main to the new main. Meter change activities also require a brief shutdown. Rehabilitation techniques such as cured-in-place lining can require an outage lasting 12 hours or more. In such cases compressed natural gas (CNG) bottles can be used but they are heavy and cumbersome. The propane air mixer has been under development since 2006. It mixes propane from a standard gas barbecue tank with air and delivers the mix at the proper heating value. A prototype was built by GTI engineers and subjected to extensive operational and end use testing, including local field testing in Chicago. Tests were successful with the exception of results with one particular brand of water heater, which shut down on high flame temperature. Phase II of this project will redesign the unit to produce a cooler flame and the testing will be repeated on a mix of appliances. Firing rate, flame temperature and emissions will be recorded. If the testing is successful (meaning all appliances performed within spec on all tests) then a new phase of the project will investigate commercialization of the unit. The benefit is better customer service using a more efficient and ergonomic method.

OTD 5.7.p - GPS/GNSS Consortium. The project objective is to facilitate the sharing of information related to the use of GPS, Global Position System [US reference] and GNSS, Global Navigation Satellite Systems (International reference) technology for utility operations. The GPS/GNSS Consortium is a cost effective way for utilities to better understand this rapidly growing technology field and how GPS technology can best be

applied to daily operations to create operational efficiencies, enhance regulatory compliance, and improve the quality of field collected data. The program activities include technology development and integration, workshops, pilot projects, demonstrations, best practices/standards development and general information sharing. Over the last two years, the GPS Consortium has focused on technology development that will reduce the cost and complexity of deploying GPS for routine construction and O&M activities. A Real Time Kinematic (RTK) base station has been installed, on GTI's main campus. This base station was built using GNSS Consortium funds in 2014 and continues to be an important asset for GNSS and GIS research at GTI. The following emerging technologies were selected for evaluation; Garmin GLO, Swift Navigation Piksi RTK Kit, uBlox Neo-7P & EVK-7P. Additionally, the following well known legacy units were tested to provide base-line comparisons; Trimble GeoExplorer XH, Navcom SF-3040, Geneq SxBlue III. GTI has completed testing and results are currently being compiled.

OTD 5.8.a - Automated Welding. This project will identify and select an automation manufacturing partner, develop a beta prototype automated welding unit, and create procedures to perform the welds on various types of tees and nipples. Throughout the project, the project team will work with the selected manufacturer(s) to assist with the implementation of the unit as a commercially viable product for the industry. A final report will document these efforts.

OTD 5.8.d - Tool for the External Classification of Pipe Contents
Research is being conducted to develop a practical tool that can detect "live" three-phase electrical cable in pipe without breaching the pipe wall. The ultimate objective is to develop an affordable tool that could be carried in each crew truck. The current project phase involves the construction and demonstration of a pre-production proto-type tool. Recently, the main focus was to debug the software required to perform the Fast Fourier Transform (FFT) on the vibrations detected on a pipe. The hardware platform was demonstrated to run the FFT library functions correctly; however, the signal level captured was somewhat low. This will need to be corrected in the hard-ware by adding amplification between the vibration sensor and the processor. The project is behind schedule and potentially will require additional time. — Software and hardware modifications are under way.

OTD 5.08.e.2ab - Enhanced Material Tracking and Traceability-Development of Standardized Protocols/Identifiers for Meters, Regulators, and Transmission Pipelines, Phase 2 (TEJ). The objective of the program is to utilize the previously established base-62 di encoding system methodology and develop a series of unique identifiers and format to characterize pertinent information for meters and regulators conforming to ANSI B109 requirements. TEJ continued its work related to proposed changes to ASTM F2897 to incorporate key data related to transmission pipeline components (pipe / appurtenances). The initial ballot for the F17.60 subcommittee ballot was submitted in December 2013 (one negative and five comments were received). The negative has been resolved and proposed ballot has been revised accordingly. The revised amendments were submitted for concurrent main and subcommittee voting. Provided that

the ballot is approved, all the necessary identifiers required to produce a 16-character code schema to mark transmission pipeline components should be in place. It is important to emphasize, even with the proposed changes in place, this simply provides all the elements needed to develop a similar 16-character code for transmission components and satisfy the objective of this phase of the program. Additional work will need to be incorporate these requirements within applicable API 5L standards and resolve underlying procurement practices and supply chain considerations within utility companies.

OTD 5.9.h - North American Outreach Manufacturer Outreach Program
Research was conducted to identify promising technologies that are under consideration but not currently under development by qualified North American manufacturers. The focus was on prospective products or technologies and that have sufficient commercial value to natural gas utilities to justify submission of a funding proposal to OTD. — A Final Report detailing project results is being prepared.

OTD 5.10.d - Remote QA QC. Development of a remote monitoring program with map based application for smartphones and tablets for field data capture and documentation will advance utility operations and quality inspections. The goal of this project will develop a mobile application with a supporting step-by-step field procedure for its use including guidelines. The focus is to develop technologies and protocols to allow operators to remotely monitor and record the quality of various operations. The quality of field work can then be monitored in real-time using a step-by-step procedure, GPS-enabled cameras, and a web-repository to capture, store, and share photos and create permanent records. Using smartphones to capture time-stamped photographic documentation during field operations improves quality and enhances quality control, particularly for new installations. Field crews, both in-house and contractors are encouraged to follow specifications and procedures because pictures are used to document important steps. Using remote QA/QC methods allows 100% of new installations to be monitored by a quality inspector or office manager and support staff, no matter where they are, they will be able to view pictures of all new installations in real-time and share information. Further, pictures are captured in a GIS environment and can be stored for long-term usage such as validating regulatory compliance, future locating, and engineering operations.

OTD 5.11.a – Dewatering System for Mains. Excessive amounts of water in gas mains can cause service outages. This “water intrusion” is particularly prevalent in low pressure areas where groundwater can enter into a gas main through leaky joints in high water table areas. The normal solution is to locate the area of water intrusion and pump the water out. This project is investigating novel methods to remove residual moisture that can be present even after water is pumped out. Two methods that have been investigated are desiccant and molecular sieve technologies that can more permanently dry out the interior of a gas main, and chemical additives such as methanol foam which can allow moisture to flow out of low points and not collect there. Once the feasibility of such methods is evaluated, the next step in the project will be to decide whether the successful

technology can be adapted to installation on a gas distribution system. This project will decrease the amount of customer outages in areas prone to water intrusion. Completed June 2015.

OTD 5.12.b – Development of a Portable Flash Fire Suppression System. During live gas operations the potential for rapid ignition of natural gas (a flash fire) is present. Although workers follow strict safety procedures and are protected with fire retardant clothing and breathing air apparatus, bodily harm can occur within milliseconds if an ignition were to occur. A true industry need exists for a system that can rapidly detect and extinguish flash fires. The project was initiated in GTI's Sustaining Membership Program (SMP). Two separate and distinct challenges were investigated, the ability of a sensor to detect a flash fire in less than ½ second, and the ability of a fire suppression system to limit injury as low as is reasonably achievable. In testing at GTI facilities both concepts were proven; a UV detector reliably detected fires within 30 milliseconds, and two separate suppression systems, high velocity air, and nitrogen extinguished the fire but each had some drawbacks needing further investigation. The Company is extremely interested in this project and Safety Dept. personnel will act as advisors to the GTI project team. A successful outcome of the project will be a portable flash fire suppression system that will effectively detect and extinguish flash fires should they occur and be simple to deploy. Enhanced worker safety and avoidance of serious or even fatal injuries is the obvious benefit of this research.

OTD 5.12.g – Evaluation and Adaptation of Kleiss Inflatable Stoppers for the US Natural Gas Industry. Current line stopping equipment in the natural gas industry has been used since inception (~ 50 years) in the same trim without substantial re-design. This equipment certainly works but is heavy, costly to maintain, and is somewhat time consuming and labor intensive when the installation of the necessary components required are taken into account. New line stopping equipment that may reduce these problematic issues, while providing the same assurance of safety and performance, could contribute to substantial time and money savings when incorporated into day-to-day operations. Through a technology search such equipment was sourced. This apparatus is produced by a European Vendor, Kleiss and Co., and has shown promising performance. The objective of this effort is to evaluate these existing medium and high pressure inflatable stoppers as an alternative to currently employed stopping equipment for use on US natural gas distribution systems. GTI will test and evaluate this inflatable stopper suite of tools (capable of stopping off line pressures of 60 psig at pipe diameters up to 24-inches). Deliverables include the development of testing criteria and a program to evaluate the current offering. In addition, it will identify the necessary modifications to the bagging system(s) and identify deployment fittings required to meet the US natural gas industry standards so that the system may be introduced and deployed for use in the US.

OTD 5.12.o and 1.14.h – Guidelines for Cast Iron Winter Operations and Cast Iron Winter Patrols study. The Company and others want to know the best methods for determining when to initiate winter frost patrols on their cast iron (CI) piping systems. Simply starting the patrols when the ground temperature or air temperature reaches a

certain limit may not be optimum. There are other factors, in addition to temperature, which may influence the propensity of CI piping to break in frost conditions. Some of these factors are diameter and pressure of the main, age, soil type, and presence of other adjacent underground facilities. The ultimate deliverable of the project is a practical guideline for operators as to when to initiate frost patrols. GTI was selected to perform the study and is investigating – through examination of LDCs' records - the frequency of breaks in the presence or absence of the potential breakage factors. The study is not complete but has already determined that diameter is a key variable and that most breaks take place on smaller diameter piping and, at least for one LDC, there is no record of breakage for pipelines larger than 18" diameter. As more data is accumulated and analyzed patterns like this should emerge. The end result should be a fact-based guideline, based on the above parameters that affect breakage, stating exactly when, and for which segments, winter frost patrols should begin.

Under OTD 1.14.h, the company did an evaluation with GTI using Picarro's CRDS and some of Picarro's latest algorithms to evaluate if this advanced leak detection system and methodology could improve our winter patrols and identify CI breaks more rapidly. The frost conditions were extreme during the course of the investigation which was ideal for the study. However, it was found that numerous passes are required and the processing of the data took a great deal of time. GTI is evaluating the data to determine if there was significant improvement in detection, however to date, this has not translated into cost savings with this approach for CI winter patrols.

OTD 5.13.d - Transmission Cut In Valve. The development of proposed cut-in valve system will give operators options for the placement of valves without the need to shut off the flow of gas along with the benefit of greatly reducing the cost of installation. This valve concept can lead to: faster installation times especially in urban environments, no need for flow control and/or bypass of gas, single excavations with no need to stop off the flow in the pipe and no need to install a bypass, enhanced safety, and lower cost of installation. This system will be a unique design that meets all material and performance expectations while delivering a compact and fast alternative to traditional valve installation methods. It will be developed to provide important performance and installation benefits to pipeline operators working under difficult conditions and with critical needs. Initially, a concept transmission EZ Valve will be developed for sizes up to 12-inches with working pressures up to 300 psig. After initial proof of concept, a 6 inch prototype valve will be constructed.

OTD 5.13.f - Low-Cost Collision-Avoidance System
Efforts are under way to develop a low-cost, low-speed, collision-avoidance system that would provide gas industry utility vehicles the ability to provide driver alerts and, when necessary, automatic braking. A complete set of laboratory-based testing scenarios was conducted using an experimental test apparatus to generate datasets that represent typical driving maneuvers. Field tests of a wireless tablet PC user interface were completed. For testing, a video system was successfully integrated with the test hardware. — A video is being prepared to demonstrate the capabilities of the system.

OTD 5.13.g - Post Disaster Risk Assessment with LiDAR and GIS. The project objective is to develop pipeline risk assessment tool to identify high risk pipe segments after post-disaster events to prioritize repair and restoration activities. This work is performed along with a DOT-funded project with Rutgers, the State University of New Jersey, to develop a mobile mapping platform that harnesses commercially available technologies to provide remote sensing data collection capabilities and to implement a GIS-based platform for data management and pipeline risk assessment. Progress thus far: the risk assessment approach and model is completed, the Bayesian Network has been integrated into a web-based computer model, and a case study is being entered into this model to estimate damage potential of pipe segments at Ortley Beach, NJ after hurricane Sandy.
The results are pending at this time.

OTD 5.14.a - RFID Testing Program. A testing program is being conducted to compare the performance and features of multiple radio frequency identification (RFID) and related technology solutions for locating and tracking gas utility assets. RFID tag installations were completed for the 3M Marker Ball, the Berntsen Infra Marker, and the Eliot Marker System. Programming of tags, along with user experience and impressions, were recorded. Assets targeted for RFID tagging included a mix of steel and PE systems from existing pipe test beds in addition to available utility hook-ups (gas, electric, and water). — The project team is in the process of locating, reading, and testing all installed above- and below-ground tags.

OTD 5.14.b - Smart Leak Repair Form. A smart leak repair form will improve the quality of data collected during the leak repair process and will lead to improved threat identification and risk assessment for DIMP. The objective is to develop a system to capture more detailed information to allow for more granular analysis to be performed, such as the identification of leak trends. Development of a Fault Tree Analysis and Decision Tree logic will be employed in this framework to resolve issues concerning proper identification of root causes and categorization of failures. The objective of the sponsors is to define an appropriate logic for electronic data collection forms.

OTD 5.14.d 2a – Tracking &Traceability for Transmission Phase 2a: Standards for MTR and Coating Reports and Phase 2b: Data Collection Technology. The goal of this project is to develop standards, guidelines, and technology for tracking and traceability of transmission pipe and components. The ability to automate the process of capturing and storing tracking and traceability information for transmission pipe will improve data quality and reduce risk. Data quality will be improved by using electronic records and barcode scanning to capture data essential for MAOP calculations and integrity management. Eliminating manual, paper-based data collection will reduce the occurrence of human errors when capturing and transferring data into the asset management system. In addition to data quality, operators will have access to pipe and coating data that can be used for threat identification and risk modeling as part of integrity management. The results of this project will provide the industry with a standardized approach for capturing pipe, appurtenance, welding and coating data. Phase 1 identified data collection requirements, developed barcode labeling specifications, and

created a design document for field data collection software. Phase 2a will create standardized forms for Mill Test Reports (MTR) and factory applied coating information. Phase 2b will create technology to capture manufacturer information using standardized barcodes and develop and test the technology in a proof-of-concept project. Phase 3 (future) will create standardized forms and technology to capture field welding and field applied coating data. GTI will propose a Phase 3 to develop standards and technology for data collection of field applied coatings and field welding operations.

OTD 5.14.f - Battery and Electric Powered Tool Evaluation, phase 1. The use of battery-powered power tools in Class 1 Division 2 environments is limited by most LDC's best practice policies; however, this project aims to investigate this topic to propose alternative ways to improve safety of these highly useful devices.

OTD 5.14.n - Construction Compliance Monitoring System. The goal of this project is to develop a risk-based Construction Compliance Monitoring (CCM) system to assist operators in ensuring and quantifying the compliance of new construction. The CCM system will be composed of a model and software. The system will assess new construction work from a system-risk perspective and will deploy audit resources based on the probability and consequence of failure for specific job sites. It will identify high risk construction activities, generate prioritized audit schedules, provide electronic audit forms on tablet computers, collect audit results, and quantify the level of compliance using industry-standard statistical methods. This project will create the CCM model and a proof-of-concept system that will be tested with one operator. Full commercialization will be pursued in a second phase, if desired by OTD. The deliverable of this project will be a model and software sufficient to prove the concept and demonstrate the value of a compliance monitoring system. Provide documentation of compliance that can be used in communicating with regulators, insurance providers, or in the event of potential litigation. The benefits of the project: Maximize the efficiency of resources devoted to ensuring compliance. Implementations of this methodology may reduce the number of field inspectors required to achieve the desired level of confidence by targeting and optimizing the deployment of audit resources, improve construction performance and efficiency, and continuously improve risk management efforts by better understanding the sources and frequency of installation error.

OTD 5.14.p - Developing Devices to Use with the Jameson Directional Insertion Tool
The objective for this project was to evaluate and modify devices or attachments for use with the Jameson insertion tool to increase the use and capabilities of live in-pipe inspection. A survey was conducted to obtain information on the current tooling and practices for live camera insertion, water removal, and digital mapping. Tests were performed to evaluate the ability of a camera to be inserted into a two-inch PE pipe through various access fittings. Tasks related to water removal and mapping-device insertion have not moved forward as survey results did not identify any devices that sponsors are currently using. — A Final Report is being prepared.

OTD 5.14.t - Methods to Detect Inserted Plastic in Steel Mains. This is an investigation into the feasibility of techniques for detecting inserted PE pipe. Three methods were considered as the most promising from an ease of field application perspective: 1) flow noise, 2) rate of cooling, and 3) modal analysis. Measurement of flow noise and/or cooling rate should work for large volume flows and the results are a function of flow rate, becoming ambiguous when volume flow decreases to zero. Using a combination of the two requires developing a method relating flow noise to cooling rate that is different for pipes with an insert and no insert. Because gas flow in a main varies greatly (including zero flow), a method independent of gas flow would be preferable for this application. An impulse modal analysis, being independent of gas flow, was seen as the most promising for identifying inserts across the largest range of flow conditions. Practical, reproducible, and easy to apply methods for generating and detecting the acoustic waveforms were identified. This technique can be used on the crown of the pipe. Measurements were performed indoors on bare, 2-inch diameter steel pipe found a large number of acoustic vibration modes. The amplitudes of the frequencies are different and depend on the insert diameter and the separation distance between the impact point and transducer location. Although the spectra are complex and additional work is required, the indoor results suggest it should be possible to distinguish among no insert and various insert diameters. Similar measurements were made in the GTI's pipe farm. The 2 and 4-inch diameter steel pipes were longer, coated with fusion bonded epoxy, and buried at both ends beneath raised earthen berms. The frequency range was greatly reduced and any differences between inserted and non-inserted pipe were small at best. It is unclear whether the reduced spectral content of the signals is due to earth and/or pipe coating attenuation, or variations in the method of attachment for the accelerometer to the external pipe surface. Additional work would be required to determine if any of the three techniques are feasible. The work performed to date has been on the impact modal analysis technique. As noted above, promising results from the indoor work did not translate to the outdoor setup with soil and coating interactions. This work was completed in 2015.

OTD 5.14.u - Evaluation of Geospatial Technologies. The purpose of this project is to evaluate two new geospatial technologies that could have engineering and operations applications for operators. The technologies to be evaluated could include wearable augmented reality devices (such as Google Glass) and handheld 3D mapping tools (such as Google's Project Tango). This project will test select technologies at GTI and local utility sites and develop recommendations for applications such as leak survey guidance, facility location and attributes, equipment repair, mapping of new and existing facilities, and emergency response. There are many advancements being made in the consumer hardware space and that the hardware and devices being developed can hold a lot of potential for the gas industry. Through efforts such as this project, research on new technologies can identify applications for the gas industry. Not every technology is going to provide the benefits that are intended, but through testing and identification of these technologies, ongoing research can bring new technologies to the gas industry. Microsoft HoloLens and other successful technologies such as Google Project Tango were identified in this project as technologies showing potential for further gas applications from which the company and the entire gas industry may benefit.

OTD 6.6.a - Keyhole Consortium. This GTI program develops continuous improvements and innovations to small hole (keyhole) technology. Keyhole excavations involve 18" diameter road openings to perform many routine operations that would traditionally require a 4 ft. x 4 ft. opening. Soil is vacuumed out and work takes place from street level using special long handled tools. This reduces paving costs and in many cases the 18" core is reused – set back in the excavation so there are no paving costs associated with the work. The Keyhole Consortium meets twice yearly; Company representatives attend with other LDCs and manufacturers. At the meeting common issues and needs are discussed and new research ideas are generated.

OTD 7.14.a - Next Generation Water Clean-up Technology. The U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration (PHMSA) has proposed IVP regulations that will require operators to verify the integrity of transmission pipes without pressure test records. These regulations could potentially require the industry to hydrotest up to 90,000 miles of in-service pipe. Cleaning and disposing of the hydrotest water is a significant component of the overall cost of hydrotesting. The objective of Phase I of this project is to conduct a technology review and business case to quantify the cost of disposing of water using current methods and the potential savings that could be achieved with new technologies. It is anticipated that development and implementation costs will be significant, thereby warranting a formal business case prior to pursuing technology development or technology transfer. Results of the industry survey taken in this project indicates that conventional management of pipeline discharge waters most often includes either hauling of the water to a publicly owned treatment works (POTW) for disposal or field-based filtering of the water through a ring of hay bales. The POTW alternative requires significant expense in transportation and in discharge fees; all costs connected with this option often exceed $0.50/gallon (2014 dollars). The hay bale alternative (whereby water is forced through a ring of hay bales) is sometimes used in the field, but the method only seems to work for the control of oils and greases and suspended solids but is not effective in removing many soluble organic compounds of concern such as benzene. Clearly, a second generation treatment system is needed that allows low cost field based treatment that is reliably compliant with water quality criteria specified in permits for water reuse and discharge to surface waters. Primary treatment systems used by industry in the past such as sedimentation and dissolved air flotation have been effective in control of suspended solids and free oil and grease. Granular activated carbon (GAC) is effective in removal of soluble organics, but becomes expensive when treating waters that are greater than 1-5 mg/l of total organic carbon (TOC). Biological treatment can be used to remove soluble organics, but the process requires too much of a footprint to be practical. Chemical oxidation, however, can be used for oxidizing most of the soluble organics while taking up a very small footprint. What is needed, however, is a chemical oxidant that is easy to handle and use in the field as a part of the integrated mobile treatment system. A review of commercial chemicals indicates that many of them are not suitable for implementation in a highly mobile, treatment system applied to 1-2 day processing of hydrostatic test waters. A list of information gaps is described in the report; these gaps can be resolved with research and development concentrated on the oxidation step of the advanced treatment flowsheet.

On the basis of this technical evaluation, it is recommended that the industry consider development and optimization of the manganese dioxide oxidative process for the conditioning of pipeline discharge wastewaters. This development work should be pursued in the context of an integrated prototype that includes all of the treatment steps that preceded and follow the oxidation process.

Cathodic Protection, Coatings and Corrosion Related

M2012-001 - Development of a Corrosion Sensor Array. This project will attempt to develop a novel method of monitoring for external corrosion on a gas pipeline by installing an "array" of sensors on a pipeline. If successful, pipeline operators will have another "tool in the toolbox" for monitoring critical pipelines for external corrosion. This project utilizes an existing microsensor-based system to provide corrosion monitoring of full sections of gas pipelines. The project will initially modify the system and then assess its suitability for the natural gas industry through lab testing. The core technology employed is the micro-linear polarization resistance sensor developed originally for aerospace applications.

OTD 2.9.c - Field Applied Pipeline Coatings. Modern pipe materials are factory coated and these coatings stand up very well as long as they are not damaged by external forces. However, in locations where field welds or other field installed fittings are present, the necessary pipeline coating needs to be field applied. Field applied coatings vary in quality and are not always installed under ideal environmental conditions such as would be present in a pipe coating factory. This project tested the performance of several different types of coatings on buried pipe at Gas Technology Facilities in Chicago.
Throughout the world, a variety of generic coating systems are commonly applied to field girth welds, including the following: (1) fusion bonded epoxy (FBE), (2) heat shrink sleeves (HSS), (3) liquid applied coatings, (4) composite systems, and (5) tapes/wraps. Eighteen (18) manufacturers supplied seventy-five (75) different coating systems for the test program. The coatings were installed by the manufacturers on a network of 8" and 24" steel piping buried in rocky, sandy, and clay-like soils. Coating systems were unearthed and examined at 2, 5, and 7 year intervals. Some coatings exhibited no rust on any of the pipes in any soil, and other coatings exhibited rust on pipe in all soil. A key conclusion of the test program is that strict adherence to the manufacturers' recommended installation procedures is absolutely necessary. A final report on project results has been prepared. The benefit is improved pipeline safety and assurance that superior products, from a long term performance point of view, are installed on company facilities.

OTD 5.9.c - Mitigating Electrical Interference on Cathodic Protection Systems.
Electrical interference can impair or negate the effect of cathodic protection systems. The objective of this project is to understand the types of interference that can be present near pipeline systems and make recommendations to mitigate the effect of these interferences. Interferences can be steady state, such as would be present from adjacent high voltage power lines or transient, caused by a lightning strike or power line surge.
To implement the project, GTI selected three host sites and installed data logging instrumentation on cathodic protection systems there. Transient events and steady state

interference data is being gathered. The results of the data gathering exercise will be recommendations for enhanced equipment or better surveillance of cathodic protection systems to better protect them. Enhanced integrity of piping systems protected by cathodic protection is the benefit of this research.

OTD 5.9.f – Cathodic Protection Monitor. The objective is to develop and deploy a Cathodic Protection Monitor prototype that stores monthly CP readings. GTI has partnered with 3M to develop a completely encapsulated, direct burial monitoring device. A 3M handheld locator/reader is used to retrieve the readings electronically from above ground without requiring a direct connection. The data, consisting of 12 sets of monthly readings, can be downloaded from the handheld devices as tabular data. The first version of the CP Monitor has been successfully tested; as a result of testing additional product requirements were identified. The objective of Phase 2 is to develop and test a modified CP Monitor prototype with some or all of the following features: ability to record AC potential readings to detect stray currents, increased data storage, improved range with the ability to capture readings from a moving vehicle, programmable data recording intervals, and ability to transfer data to other handheld devices via Bluetooth for direct GIS integration. The benefit is improved monitoring of CP performance on protected piping, with the potential cost savings of making mobile readings

OTD 5.11.n – Quality Control Procedure for High Potential Anodes. The Company recently has been experiencing quality problems with magnesium anodes as delivered from manufacturers. Anodes that appear – upon visual inspection – to be sound have been experiencing premature failures in the field. Quick and simple voltage tests may initially reveal that the anode is generating the required voltage potential but this may be indicative of good quality of the surface layer of the anode only. If the entire anode is not of the same quality and purity the anode will deteriorate prematurely. The standard industry test for measuring anode purity, ASTM G97, is expensive and time consuming and it is not practical to conduct this test for all new anodes received. Therefore, there is an industry need for a quicker test that can validate the requisite quality and purity of anodes. GTI has received anodes from project participants and is currently evaluating alternate methods of testing them that can give results similar to the G97 test. As an indication of the need for this project, GTI reports that the project has experienced delays due to the time consuming nature of the G97 test, which is being performed in parallel as a control. The benefit is better assurance of the quality of materials received and installed in the company's gas system.

OTD 5.12.n – Advanced Tools for Improved AC Corrosion Prevention and Mitigation. Alternating Current (AC) corrosion is not common but can occur if gas mains are in proximity to railroads or overhead electric transmission lines. When it does occur, the corrosion rates can be rapid, thus the need for the Company to quickly identify and mitigate the occurrence of AC corrosion. The company is working with GTI on this project and they have proposed a two part solution, a model to predict rates of AC corrosion, and a calculator to determine the most effective mitigation measure. The project will draw heavily on existing work done by the National Association of Corrosion Engineers (NACE) and the Company's and other funders' experience. The final

deliverable of the project will be the model and calculator, which can be used to prioritize inspections and gauge the impact of various mitigating measures on both new and existing gas pipelines.

OTD 5.14.x - Risk-Based Atmospheric Corrosion/Leak Survey Considerations
A study reviews historical and current data on atmospheric corrosion of indoor service piping. A detailed review of the published, peer-reviewed literature related to field data on indoor corrosion was made. A comparison of the fundamental principles of indoor and outdoor atmospheric corrosion was made. The research conducted compares and contrasts indoor atmospheric corrosion to outdoor corrosion for iron and steel piping materials. In addition, thousands of recent inspections in NY and New England States were completed on outdoor and indoor services by operators the data was collected and statistically analyzed to determine the trends and drivers behind the observed corrosion rates. A similar analysis was completed on exclusively indoor leak survey data from LDC operators. Finally, all the findings were summarized and related to risk-based considerations for setting appropriate inspection intervals for indoor service piping. This art of the study was completed in late 2014.

General and Other Areas Not Covered Elsewhere

M2001-013 - Millennium Website Development. A project for maintenance and upgrading of NYSEARCH's website and for use by the NY LDCs who utilize NYSEARCH as a clearinghouse for reporting to the NY PSC on the use of the Millennium R & D funds

M2002-008 - Oracle Technology Concept Investigation. Through the NYSEARCH research consortium, the Company and others fund a concept known as “Oracle.” The purpose of this program is to look outside the gas industry for novel technology solutions to gas industry needs. In the past, technologies from the military, biomedical, and telecommunications industries have been tracked. More recently, our focus has been sensor technologies using fiber optics or nanotechnology, and material science advances. Applications from these industries, when identified, will be funded as separate projects. An example of that is a current effort to take nanocomposite particles used in plastic in other industries and create self-healing PE pipe. Another example that came from this is the methane sensor using tuning fork technology.

OTD 5.14.c - Improving Cybersecurity for LDCs - Needs Identification & OTD 5.15.a Cybersecurity Collaborative. Initiated in February 2014 an initiative to review and to provide information on the status of cybersecurity R&D activities for LDCs and identify the short and long-range needs for cybersecurity capability improvement for LDCs. A workshop was conducted on April 16-17, 2014 at GTI facilities in Des Plaines, IL. Day 1 included presentations by representatives from GTI, AGA, DHS and SRI to orient the attendees to cyber related activities focused on the energy sector and natural gas specifically. Day 2 was dedicated to sharing lessons learned and identifying technology needs and gaps, and prioritizing project ideas. A summary report was prepared which identifies the industry need and business value of addressing

cybersecurity issues, and summarizes the cybersecurity lessons learned for the participating utilities, A follow on effort under OTD 5.15.a continues as a multi-year collaborative program between natural gas distribution companies and the Department of Homeland Security (DHS) to address the high priority cybersecurity issues of participating members through a focused outreach and education process and a technology evaluation and transfer initiative.

OTD 6.14.a - Quality Audit Program for Natural Gas Utility Suppliers. Distribution Integrity Management regulations encourage utility companies to place a new focus on supplier and supply chain quality. Identifying threats and mitigating risks starts with the manufacturing process. Reducing supply chain risk requires a comprehensive and well-coordinated supplier audit program to ensure that the integrity of the supply chain is controlled and that the supplier is following policies and procedures required by customers and regulators. The purpose of this effort is to develop an audit program and provide natural gas utility operators with a mechanism to collaboratively audit supplier's quality management systems. The program will conduct an independent and unbiased assessment on behalf of participating operators to provide a reliable and standardized approach for monitoring suppliers. Participating operators will benefit from a collaborative program by creating efficiencies and promoting information sharing. Supplier audits identify non-conformances in manufacturing, shipping, engineering change, invoicing, and quality processes. After the audit, the supplier and auditors jointly identify corrective actions which must be implemented by the supplier within an agreed-upon timeframe. A future audit ensures that these corrective actions have been successfully implemented. While the need for enhanced quality audits and monitoring programs is increasing, the availability of resources to conduct these programs is decreasing due to operator's focus on operations and efficiencies. Therefore, there is a need for a coordinated collaborative audit program to allow gas utilities to efficiently monitor supplier processes. Participation in the collaborative program will provide value in the following ways: create efficiencies and cost savings by consolidating audits into one program, increase the number of audits performed, create leverage and increase influence with suppliers, utilize RAB/IRCA certified auditors with extensive experience, provide a high quality audit due to consistency and standardization of audit methodology and allow internal resources to focus on the core business rather than auditing. National Grid has participated in the development and pilot which has helped us review and improve our own auditing process but we are currently evaluating if we will continue in this GTI program.

Joint Industry Projects

The following three projects have been are jointly funded and managed between DET NORSKE VERITAS, DNV, and various industry co-funders:

Development of Industry Best Practices for Hot Tap Branch Connections Joint Industry Project (JIP) – a welding procedure is being developed and draft sent out to the group for comments, particularly for preheat. Concerns for maintaining preheat on a flowing pipeline are to be addressed.

Development of Industry Best Practices for Girth Weld Repair The objective of this JIP is to develop industry best practice for repair of pipeline girth welds during new construction activities, which will include the development and qualification of a suite of repair welding procedures in accordance with Section 10 of the Twenty-first Edition of API 1104. A guideline for selecting an appropriate procedure for a given application will also be developed. The scope will also include the development of guidance pertaining to other technical aspects of girth weld repair and repair welder qualification (e.g., preheating requirements, inspection requirements, time delay prior to inspection, minimum-required and maximum-allowable repair length, practical limits on wall thickness, etc.) that will be used to develop a generic company specification for repair of pipeline girth welds during new construction.

Validation of the ASME Procedure for Estimating Lower Bound Yield Strength of Pipe from Hardness Data. Forty-nine pipe samples representing a wide range of age, size, grade, composition, and manufacturing method were tested to demonstrate the validity of using hardness test data to estimate lower bound yield strength (YS) of steel pipe. Three different types of field portable hardness testers were used on each pipe sample. The hardness testing was performed in accordance with ASME CRTD-Vol. 91. The hardness test results were converted to estimated lower bound YS values using the correlations described in ASME CRTD-Vol. 57. The estimated lower bound YS was compared to the results of standard API 5L tensile tests. In addition, the metallurgical attributes of each pipe were characterized to determine if certain subsets of pipes produced better (or worse) correlations of estimated lower bound YS to YS determined from tensile tests. The results showed that hardness data can be used to estimate conservative values of lower bound YS using a range of different confidence levels.

National Grid Managed Projects

National Grid funds projects outside the NYSEARCH and OTD consortia and manages them ourselves or jointly with other LDCs. The following two projects are jointly funded and managed between National Grid Downstate and Consolidated Edison Co (Con Ed)

M2001-009 - Construction Interference Cost Reduction (CONCORD) Program. National Grid and Con Edison, along with the Urban Utility Center of Polytechnic Institute of New York, are working with New York City to introduce trenchless technologies to the city's construction program. Trenchless technology – as compared to traditional "open cut" construction – can save National Grid and Con Edison significant dollars by eliminating the need to relocate our gas facilities if they interfere with the city's new construction. We have introduced new trenchless technologies to the city's engineers, conducted training programs, performed lab testing, and these efforts have culminated in New York City's decision to rehabilitate two miles of a major water main in Manhattan via a trenchless method. This method involves insertion of a plastic liner into the existing cast iron water main and few adjacent gas facilities will need to be relocated. Con Ed estimates significant savings. If this program is successful and NY

City adopts trenchless technology for future construction, the savings to National Grid and Con Ed could be significant for years to come.

M2002-015 Cast Iron Sealing Robot (CISBOT): National Grid and Con Edison jointly fund and manage this project to design, construct and test a live, tethered robot that will internally seal cast iron joints. National Grid has the highest inventory of cast iron pipe in the nation, over 6000 miles, with over 2600 miles in the State of New York alone (Source, US DOT report). Cast iron is a very durable material but over time the joints – mechanical connections packed with jute and lead – can dry out and are the source of leakage. National Grid's predecessor company, KeySpan, partnered with Con Edison of New York to jointly fund the development of CISBOT. The robot was built by ESI Corp of Toronto, Canada. Upon completion of the robot Con Ed and National Grid entered into an agreement with ULC Robotics, a small high tech firm located on Long Island, to 'commercialize' the device and ultimately become the service provider for the CISBOT services. This is a typical business plan for high tech deployment in the gas distribution sector; ULC Robotics performs this type of work as their main line of business. To date, National Grid has spent over $2.2 Million on the project, with a similar amount funded by Con Edison. CISBOT is designed to seal joints in 16" through 36" diameter cast iron gas mains operating at pressures up to 25 psi. An excavation will be dug at a convenient point along the gas main and a special fitting is installed on the main which allows a 12" opening to be cut into the main in "live" conditions with no shutdown required and no blowing gas. (This is a fairly common procedure in the gas industry.) The CISBOT robot is then inserted into a launch tube and the launch tube is attached to the fitting on the main. The launch tube is purged of air with nitrogen and then a valve is opened and natural gas fills the launch tube. The robot is then lowered into the gas main. A tether connects the robot with external power and communication, and a small tube in the tether contains the anaerobic sealant which is used to seal the joints. An operator drives the robot using onboard cameras as a guide and stops at the first joint. A small hole is then drilled into the joint at a predetermined spot. Once the hole is drilled, a nozzle is inserted up into the drilled hole and anaerobic sealant is pumped into the hole, saturating the joint. Cameras on the robot are positioned to view the wicking action of the anaerobic fluid and pumping is stopped when the operator judges that a particular section of the joint is filled with sealant. The robot is then repositioned to a different "clock position" around the circumference of the joint and the drilling and sealing operation is repeated. Once the operator judges that the joint is sealed the robot will travel down to the next joint and the process is repeated.

CISBOT is undergoing an extensive program of field demonstrations over the past three years in New York City and Boston. Costs for the demonstrations outside NY State are borne by the area conducting the demonstration. In parallel with the demonstrations, the Company and Con Edison are negotiating a Commercial License with ULC Robotics. The cost of the service will be determined by ULC Robotics prior to their offering the service as a commercial business. National Grid NY and Con Ed will receive a discount from the stated list pricing. Because the final cost of the service has not yet been determined, it is difficult to accurately predict savings but assumptions can be made.

The basis for our assumed savings of $2.5M annually is to assume that CISBOT is deployed to a main segment where 50% of the joints are or will soon be leaking. Per job that's about 15 joints at an estimated cost of $3000 per joint to repair, total cost $45,000. This figure can vary depending on the final pricing structure set by ULC Robotics. Standard repair including a tight sheeted pit is estimated at $20,000 per repair for total repair cost of $300,000. Actual costs for tight sheeted pits in congested urban areas have been reported as much higher but this is a conservative estimate. Based on these assumptions the net savings is about $255,000 per job. Assuming full successful deployment of CISBOT, 10 such jobs per year could be performed, resulting in annual savings of $2,550,000.

National Grid expects to deploy this technology in its large diameter cast iron mains in New York State and Massachusetts. Any royalties received will be returned to NY ratepayers through the Millennium Fund.

Attachment 2 shows spending for these projects described above.

National Grid Gas R&D Spending

Includes Ngrid Downstate (KeySpan) and Ngrid Upstate (NMPC)

Calendar Year Expenditures ($)

	Actual		Projected		
Year	**2014**	**2015**	**2016**	**2017**	**2018**
National Grid Internal Program					
Utilization	$ 104,800	$ 211,426	$ 758,574	$ 170,000	$ 170,000
Operations	$ 57,708	$ 28,476	$ 200,000	$ 263,000	$ 263,000
Ngrid Labor and Expenses	$ 229,692	$ 184,741	$ 201,640	$ 207,689	$ 228,094
TOTAL INTERNAL	**$ 392,200**	**$ 424,643**	**$ 1,160,214**	**$ 640,689**	**$ 661,094**
National Grid Millennium Program					
NYSEARCH Projects	$ 2,265,234	$ 1,311,235	$ 1,571,000	$ 1,687,000	$ 1,150,000
OTD Projects	$ 750,000	$ 870,279	$ 750,000	$ 750,000	$ 750,000
National Grid Projects	$ 40,000	$ 103,502	$ 352,000	$ 400,000	$ 450,000
TOTAL MILLENNIUM	**$ 3,055,234**	**$ 2,285,016**	**$ 2,673,000**	**$ 2,837,000**	**$ 2,350,000**
TOTAL MILLENNIUM AND INTERNAL	**$ 3,447,434**	**$ 2,709,659**	**$ 3,833,214**	**$ 3,477,689**	**$ 3,011,094**
NYSERDA Assessment	$ 3,565,124	$ 4,906,042	$ 5,000,000	$ 5,250,000	$ 5,550,000
TOTAL R&D PROGRAM	**$ 7,012,558**	**$ 7,615,701**	**$ 8,833,214**	**$ 8,727,689**	**$ 8,561,094**

Note: Total spend, from books of Company

PROJECT NUMBER	PROJECT	START DATE	END DATE	TOTAL NGRID COMMITMENT	TOTAL SPEND 2013	TOTAL SPEND 2014	TOTAL SPEND 2015	TOTAL NGRID SPEND Joe YEARS
M-2000-001	Variable length sleeve - NYSEARCH	2000	2013	$ 147,356		$ 29,586.33		$ 111,970.00
M-2000-004	Explorer Commercialization, Phase I	2000	2006	$ 341,239		$ 14,906.96		
M-2001-002	Mgmt of Impacted Sediments - NYSEARCH	2001	2011	$ 430,061				$ 430,061.00
M-2001-003	Cased Pipe Risk Assessment Model	2001	2011	$ 274,472		$ 4,007.04		$ 184,501.00
M-2001-005	PipeHawk Hand-Held Pipe Locator - NYSEARCH	2001	2013	$ 435,090		$ 23,892.72		$ 392,895.00
M-2001-006G	Development / Testing / Commercialization of GASNET(tm) - Phase V	2001	open	$ 392,485			$ 31,593.94	
M-2001-009	Interference Avoidance/UUC Technology Demo Lab	2001	2010	$ 475,000				$ 446,000.00
M-2001-013	Millennium Web Development	2001	ongoing	$ 37,998		$ 5,751.81	$ 1,612.19	
M-2001-014	InspectionTool for Unpiggable Facilities - Automatika (TIGRE)	2001	2011	$ 967,261	$ (9,098.34)			$ 959,781.00
M-2002-008	Technical Expert (Oracle) to ID Quantum Leap Technologies	2002	ongoing	$ 53,931		$ 13,585.11	$ 179.87	$ 29,396.00
M-2002-011	FFT AUra Damage Prevention Systems - Testing Program - Phase III	2002	open	$ 202,380		$ 109,480.05	$ 43,194.73	
M-2002-015	CISBOT-Live IP CI Joint Sealing (KSE/ConED/ESI/ULC)	2002	2013	$ 2,356,825				$ 2,219,476.00
M2002-018	Infrasonic Sensor for Remote Pipeline Monotoring - NYSEARCH	2002	2010	$ 129,711				$ 104,858.00
M2003-009	Explorer II	2003	2012	$ 483,030		$ 24,727.35		$ 451,452.00
M2005-003	Test Bed Maintenance and Improvements	2005	ongoing	$ 110,108		$ 518.11	$ 1,225.31	
M2005-005	Gas Interchangeability for LDC Infrastructure	2005	2014	$ 753,336		$ 96,150.43	$ 25,514.42	$ 644,948.00
M2006-002	Butt Fusion Joint Integrity	2006	2011	$ 70,198		$ 9,776.81		$ 53,213.00
M2007-001	Mini-camera for Cased Crossings	2007	2012	$ 150,952		$ 10,491.88		$ 228,563.00
M2007-003	Multi Technology Validation Testing for Cased Pipe Applications	2007	2013	$ 73,315		$ 897.85	$ 2,952.00	$ 49,676.00
M2007-005	Testing Program for Remote Inspection-Transkor	2007	2012	$ 133,080		$ 15,387.64	$ 1,803.50	$ 75,901.00
M2007-007	Technology Advancement in Damage Prevention Tools and Communications	2007	2011	$ 91,973		$ 7,268.87		$ 64,243.00
M2008-001	Third Party Detection - Magal	2008	2013	$ 58,297		$ 5,522.13	$ 4,202.49	$ 29,419.00
M-2008-005	Developing Platelet Technology for use in Gas Transmission and Distribution Centers	2008	open	$ 23,280		$ 23,279.52		
M2008-006	Expand Function of No Blow Tools to Reduce GHG	2008	2012	$ 122,329		$ 6,055.00		$ 82,078.00
M2008-010	UV Degradation of PE Pipe	2010	2013	$ 14,125				$ 8,070.00
M2009-001	Holistic Review of DIMP Practices and Models	2009	2012	$ 48,750		$ 3,995.78		$ 44,409.00
M2009-002	Mercaptan Sensor Development	2009	open	$ 330,462		$ 60,282.16		$ 266,030.00
M2009-003	Adaptation Study	2009	2012	$ 23,500				$ 23,500.00
M2009-007	Particulate Dispersion Study	2009	2011	$ 75,000				$ 60,516.00
M2009-008	Ultrasonic Evaluation System for PE Butt Fusion	2009	open	$ 133,700		$ 20,632.90		$ 2,079.00
M2010-001	Service Tee Renewal	2010	open	$ 73,170		$ 27,692.85		$ 20,118.00
M2010-002	Methane MR Sensor Development	2010	open	$ 126,730		$ 12,318.70	$ 41,955.00	$ 23,265.00
M2010-003	PCB Absorption in PE Piping	2010	2013	$ 194,000		$ 60,613.68		$ 121,228.00
M2010-004	Soil Vapor Intrusion	2010	2012	$ 83,100		$ 39,199.82		$ 43,877.00
M2010-005	Guided Wave Test Program	2010	2012	$ 175,000				$ 95,082.00
M2011-001	Self Healing Pipe	2011	open	$ 232,442		$ 123,440.62	$ 45,986.48	$ 7,397.00
M2011-002	Storage Effects on Gas Quality	2011	2013	$ 26,555		$ 9,470.17		$ 12,628.00
M2011-003	Odor Masking	2011	open	$ 126,695		$ 89,198.22		$ 23,158.00
M2011-004	Carbon Calculator	2011	open	$ 24,450		$ 1,156.83		$ 12,234.00
M2011-005	Fiber Sen System Development and Testing	2011	open	$ 71,248		$ 32,464.79	$ 28,342.19	$ 6,316.00
M2011-006	Robotics Supporting Technologies	2011	open	$ 1,020,009		$ 411,841.51	$ 169,306.28	$ 152,941.00
M2011-007	Cased Pipe Inspection via Vents	2011	open	$ 386,760		$ 168,393.96	$ 94,646.85	$ 41,630.00
M2011-008	BioBall Test Program	2011	2013	$ 37,630		$ 37,630		$ -
M2011-009	Explorer 30 - 36"	2011	2013	$ 500,000	$ 64,500			$ 435,000
M2012-001	Development of Corrosion Sensor Array	2012	open	$ 72,310		$ 20,811	$ 49,013	$ -
M2012-003	Enterprise Level Assessment of Data Management Systems	2012	2014	$ 33,900		$ 33,900		$ -
M-2013-001	Explorer 16/18 - Inspection of Unpiggable Pipelines	2013	2015	$ 1,230,915	$ 307,730	$ 615,460	$ 307,725	$ 1,230,915
M-2013-002	Non-Destructive Inspection of Gas Pipes Using AMR Sensors for Eddy Current Testing (ECT)	2013	open	$ 342,668		$ 2,883	$ 45,940	
M-2013-003	Integrated Nanosensors for Analysis of Chemical Compounds in Natural Gas Applications (WKU Advanced Chemical Sensor)	2013	open	$ 189,885		$ 4,563	$ 152,422	
M-2014-001	Aeryon sUAS Technology - Regulatory & Technology Assessment	2014	open	$ 131,880			$ 10,396	
M-2014-002	Leak pinpointing inside pipe	2014	open	$ 27,380			$ 8,717	
M-2014-003	Picarro Methane Emissions Analyzer System	2014	open	$ 129,748			$ 129,748	
M-2014-004	Technology Evaluation & Test Program for Quantifying Methane Emissions Related to Non-Hazardous Leaks	2014	open	$ 54,210			$ 14,825	
M-2014-005	Critical Valve Operability	2014	open	$ 18,155			$ 7,033	
				$ 14,248,084	$ 363,132	$ 2,177,234	$ 1,218,335	$ 9,188,824
Keyspan dues					$ 55,000	$ 55,000	$ 60,000	
NMPC dues					$ 33,000	$ 33,000	$ 33,000	
					$ 451,132	**$ 2,265,234**	**$ 1,311,335**	
OTD 1.08.a	GPS-Based Excavation Encroachment Notification	2008	open	$ 134,269	$ 19,176			$ 134,269
OTD 1.08.a.CA	GPS Based Excavation Encroachment Notification for ROW Monitoring- CA (GTI)	2008	open	$ 33,142	$ 33,142			
OTD 1.08.c	GPS-Enabled Leak Surveying and Pinpointing (see 1.9.a)	2008	open	$ 50,000				
OTD 1.8.f	Electromagnetic and Acoustic Obstacle Detection Refund	2004	2011	$ 24,599	$ (12)			$ 24,599
OTD 1.8g	Acoustic Sewer Lateral Locator	2008	2012	$ 80,289	$ 7,300			$ 72,989
OTD 1.09.a	GPS Leaks - Phase 2 (from 1.8.c)	2009	2013	$ 129,080	$ (437)			$ 121,780
OTD 1.h and 1.10.c	Hand Held Acoustic Pipe Detector and tech transfer	2003	2013	$ 287,260				$ 287,260
OTD 1.10.e	Enhancing Damage Prevention in New York	2010	2015	$ 16,500				
OTD 1.11.a	Chemical Methods to detect crossbores	2011	2011	$ 2,870				$ 2,870
OTD 1.11.c	Low-Cost MEMS Methane Sensor Platform Phase 1	2011	2015	$ 30,000				$ 30,000
OTD 1.11.e	Cross Bores - National Database and Risk Model	2011	open	$ 35,000	$ 3,000			$ 35,000
OTD 1.12.b	Cross-Bores Detection Using Mechanical Spring Attachment	2012	2014	$ 10,000	$ 5,314			$ 10,000

PROJECT NUMBER	PROJECT	START DATE	END DATE	TOTAL NGRID COMMITMENT	TOTAL SPEND 2013	TOTAL SPEND 2014	TOTAL SPEND 2015	TOTAL NGRID SPEND Joe YEARS
OTD 1.14.d	Field Measurement of Leak Flow Rate	2014	open	$ 9,994		$ 5,000	$ 4,994	
OTD 1.14.g	Evaluation of Residential Methane Detectors	2014	open	$ 85,000		$ 85,000		
OTD 1.14.g.2	Evaluation of Residential Methane Detectors-Phase 2	2014	open	$ 32,097		$ 15,446	$ 10,000	
OTD 1.14.g.2a	Evaluation of Residential Methane Detectors-Phase 2 Pilot	2014	open	$ 175,000				
OTD 1.14.h	Picarro Surveyor Winter Patrol Implementation	2013	2015	$ 572,500		$ 25,000	$ 547,500	
OTD 2.07.a	2.7.a Refund				$ (9,014)			
OTD 2.8.e	Structural Liners and Sleeves - Technology Search	2008	2013	$ 12,132				$ 12,132
OTD 2.9c	Field Applied Coatings	2009	2012	$ 67,000				$ 67,000
OTD 2.11.a	Development of a System for Repair of Above Ground Leaks	2011	open	$ 44,611	$ 4,375			$ 40,236
OTD 2.11.d	RSD X-Ray for Metallic Pipe Assessment - Testing and Validation	2011	2012	$ 20,000				$ 20,000
OTD 2.11.d Refund	2.11.d Refund						$ (2,737)	
OTD 2.12.e	Selection of Liners Composites for the Rehabilitation of Distribution and Transmission Lines	2012	2015	$ 15,000	$ 15,000			
OTD 2.13.b	Guidelines for Special Permits for Structural Composite Rehabilitations	2013	open	$ 38,000	$ 38,000			
OTD 2.13.c	PHMSA Accelerated Dynamic Testing for Long Term Evaluation of Liners and Composite Pipe Materials add (PHMSA-21501)	2013	open	$ 39,063	$ 25,000	$ 14,063		
OTD 2.14.a	Composite Repair Wrap for Polyethylene (PE) Systems	2014	open	$ 5,000		$ 5,000		
OTD 2.14.b	Pipe System Repair Technique	2014	open	$ 40,000		$ 20,000	$ 20,000	
OTD 2.14.c	Assessment of Squeeze off Location for Small Diameter Polyethylene (PE) Pipe and Tubing	2014	open	$ 8,190		$ 5,000	$ 3,190	
OTD 2.14.d Refund	2.14.d Refund	2014		$ (17,964)		$ (17,964)		
OTD 2.14.d	Universal PE Entry Fitting	2014	cancelled	$ 20,000		$ 20,000		
OTD 2.14.e	Guidelines/Best Practices for Scraping PE Pipe and Fittings	2014	open	$ 1,251		$ 1,000	$ 251	
OTD 2.b	Service Applied Main Stopper			$ 152,078				
OTD 3.8a	Jackhammer Noise Abatement Issues	2008	2010	$ 20,000				$ 36,463
OTD 3.9a	Backfill Evaluation & Ecoroads	2009	2012	$ 24,295				$ 30,869
OTD 3.14.a	Soil Compaction Supervisor Enhancements	2014	open	$ 36,355		$ 25,000	$ 8,934	
OTD 3.14.b	Update ASTM Standard of DCP Compaction Control	2014	open	$ 1,000		$ 1,000		
OTD 4.7.g	Yield Strength	2007	2012	$ 27,672	$ 2,500			$ 25,172
OTD 4.08.a	Guided Wave Validation as Hydro Equivalent	2008	2015	$ 52,843				
OTD 4.8.i	Extended Reassessment Interval Validation Through Dielectric Wax Casing Fill	2008	2012	$ 58,929				$ 58,929
OTD 4.9a	Leak vs. Rupture Boundary	2009	2012	$ 68,048				$ 68,048
OTD 4.9.a Refund	4.9.a Refund			$ (99)			$ (99)	
OTD 4.11.f	Understanding Threat Interactions for Risk Analysis (GTI)	2011	2013	$ 30,000				$ 30,000
OTD 4.12.b	Correlating Pipeline Operations to Potential Crack Initiation Growth Arrest (GTI)	2012	open	$ 74,678	$ 30,000	$ 14,678		$ 30,000
OTD 4.13.a	DIMP Consequence Model	2013	2015	$ 55,200	$ 30,000	$ 25,200		
OTD 4.13.b	Validation of 3D Scanners for Anomaly Assessment	2013	2013	$ 25,000	$ 25,000			
OTD 4.13.c.2	PHMSA EMAT Sensor for Small Diameter and Unpiggable Pipe Phase 2 Construct and test field ready prototype	2013	open	$ 10,000			$ 5,000	
OTD 4.13.d.3	Hydro-testing Alternative Program - Phase 3	2013	open	$ 8,658		$ 5,000	$ 3,658	
OTD 4.14.a	Fitting and Component Catalogue for IVP	2014	open	$ 5,000		$ 5,000		
OTD 4.14.c	Surface Indentation for Material Characterization Correlation of Surface Properties Based on Vintage	2014	open	$ 58,301		$ 30,000	$ 28,301	
OTD 4.e	Inspection Platforms for Unpiggable Pipelines (NYSEARCH)			$ 303,963				
OTD 5.06.e	Portable Propane Air Residential Temporary Gas Supply	2006	open	$ 90,062	$ 14,851			
OTD 5.07.f	Automated Meter Shut-Off Device (AMS)	2007		$ 47,596				
OTD 5.07.p	5.07.p (GTI) GPS Consortium	2007	open	$ 15,000				
OTD 5.08.a.2	5.08.a.2 Development of Automated Welding Unit for Installing Laterals – Phase 2 (GTI)	2008	open	$ 42,500	$ 20,000	$ 22,500		
OTD 5.08.d.3	5.08.d.3 Tool for External Classification of Pipe Contents, Phase 3	2008	open	$ 1,000		$ 1,000		
OTD 5.8e	Gas Material Traceability	2008	2012	$ 77,008	$ 4,020			$ 72,988
OTD 5.08.e.b (b)	5.08.e.2ab Enhanced Material Tracking and Traceability-Development of Standardized Protocols/Identifiers for Meters, Regulators, and Transmission Pipelines, Phase 2 (TEJ)	2008	open	$ 6,749		$ 5,000	$ 1,749	
OTD 5.08.e.a (a)	5.08.e.a (a)Enhanced Material Tracking and Traceability Development of Standardized Protocols Identifiers For Meters and Regulators	2008	open	$ 5,000				
OTD 5.08.e.b (b)	5.08.e.b (b) Enhanced Material Tracking and Traceability Development of Standardized Protocols Identifiers For Transmission Pipeline	2008	open	$ 30,916	$ 7,916			$ 30,916
OTD 5.08.k Refund	5.08.k Refund				$ (287)			
OTD 5.08.l Refund	5.08.l Refund				$ (271)			
OTD 5.9c	Mitigating Elec. Interference on Cathodic Protection Systems	2009	2012	$ 80,522				$ 80,522
OTD 5.09.f	CP Monitor Prototype Modification and Field Trials Phase 2	2009	2015	$ 46,739	$ 15,326	$ 6,413		$ 25,000
OTD 5.09.f Refund	5.09.f Refund						$ (546)	
OTD 5.09.h	5.09.h North American Manufacturer Outreach			$ 1,893				$ 1,893
OTD 5.9j	Gas Distribution Model	2009	2012	$ 103,600				$ 103,600
OTD 5.9k	Low Impact Marking Study	2009	2012	$ 50,261				$ 50,261
OTD 5.10.d.2	5.10.d.2 Remote Field QA/QC Phase 2	2010	open	$ 73,450		$ 40,000	$ 33,450	
OTD 5.10.f Refund	5.10.f Refund			$ (21,616)	$ (21,616)			
OTD 5.10.f	Cold Assisted Pipe Splitting (CAPS), Phase 1	2010	2012	$ 46,615				$ 46,615
OTD 5.10.g	Indoor Air Quality and Safety Issues	2010	open	$ 25,000				$ 25,000
OTD 5.11.a	Dewatering Systems for Mains	2011	2013	$ 66,927			$ 2,000	$ 66,927
5.11.a Refund	5.11.a Refund						$ (229)	
OTD 5.11.m	Intelligent Utility Installation Process	2011	2014	$ 278,297	$ 191,000	$ 18,344		$ 68,953
OTD 5.11.n	Quality Control Procedure for High Protential Anodes	2011	2013	$ 44,929	$ 4,045			$ 40,884
OTD 5.11.n.2	5.11.n.2 Quality Control Procedure for High Potential Anodes – Phase 2	2011	2015	$ 20,000	$ 20,000			
OTD 5.12.b	Development of a Portable Flash Fire Suppression System (PFFSS)	2012	2014	$ 34,430	$ 14,430			$ 20,000
OTD 5.12.b.2	5.12.b.2 Development of a Portable Flash Fire Suppression System (PFFSS) Phase 2	2012	open	$ 10,000		$ 10,000		
OTD 5.12.g	Large Diameter Medium Pressure Inflatable Stoppers Evaluation of Kleiss System for the U.S. Natural Gas Industry	2012	2014	$ 20,000	$ 8,007			$ 20,000

PROJECT NUMBER	PROJECT	START DATE	END DATE	TOTAL NGRID COMMITMENT	TOTAL SPEND 2013	TOTAL SPEND 2014	TOTAL SPEND 2015	TOTAL NGRID SPEND Joe YEARS
OTD 5.12.n	Advanced Tools for Improved AC Corrosion Prevention and Mitigation	2012	2013	$ 70,000	$ 35,000			$ 35,000
OTD 5.12.o	Guidelines for Cast-Iron (CI) Winter Operations	2012	2013	$ 108,000	$ 48,000			$ 60,000
OTD 5.12.o.2	Assessment of Frost Impact on Cast Iron Pipes Phase 2	2012	2015	$ 37,410		$ 37,410		
OTD 5.12.p	NG Appliance Immersion Study	2012	2015	$ 104,606	$ 104,606			
5.12.p refund	5.12.p Refund	2012					$ (5,722)	
OTD 5.13.c	PE Pipe Splitting Technical Evaluations, Enhancements, and Standardization of Tool Kits	2013	open	$ 30,000	$ 30,000			
OTD 5.13.d.2	Transmission Cut In Valve Phase 2	2013	open	$ 50,000		$ 25,000		
OTD 5.13.f	Low Cost Collision Avoidance System	2013	open	$ 18,338	$ 10,000	$ 8,338		
OTD 5.13.g	Post Disaster Risk Assessment with LiDAR and GIS	2013	open	$ 50,000	$ 25,000	$ 25,000		
OTD 5.14.a	RFID Testing Program	2014	open	$ 25,277		$ 15,000	$ 10,277	
OTD 5.14.b refund	5.14.b Refund	2014		$ (829)			$ (829)	
OTD 5.14.b	Smart Leak Repair Form	2014	open	$ 18,500		$ 18,500		
OTD 5.14.c	Improving Cybersecurity for LDCs-Needs Identification Workshop	2014	open	$ 5,000		$ 5,000		
OTD 5.14.d	Tracking and Traceability for Transmission Pipe Materials	2014	open	$ 15,000		$ 15,000		
OTD 5.14.d.2a	Tracking and Treaceability for Transmission-Phase 2a Standards for MTR and Coating Reports, Rev	2014	open	$ 19,141		$ 10,000	$ 9,141	
OTD 5.14.d.2b	Tracking and Treaceability for Transmission-Phase 2b Data Collection Technology, Rev	2014	open	$ 23,725		$ 10,000	$ 9,091	
OTD 5.14.f	Battery and Electric Powered Tool Evaluation Phase 1	2014	2015	$ 20,000		$ 20,000		
OTD 5.14.j	Residual Gas Removal Identify Technologies Limitations Best Practices	2014	open	$ 15,000		$ 15,000		
OTD 5.14.n	Construction Compliance Monitoring System	2014	open	$ 29,234		$ 15,000	$ 14,234	
OTD 5.14.p	Pipe Insertion Technologies - Develop Devices to Use with Jameson Directional Insertion Tool	2014	open	$ 1,663		$ 1,000	$ 663	
OTD 5.14.t	Methods to Detect Inserted Plastic in Steel Mains	2014	2015	$ 11,909		$ 11,298	$ 611	
OTD 5.14.t Refund	5.14.t Refund	2014		$ (27)			$ (27)	
OTD 5.14.u	Evaluation of New Geospatial Technologies	2014	2015	$ 5,125		$ 5,000	$ 125	
OTD 5.14.u Refund	5.14.u Refund	2014		$ (1,221)			$ (1,221)	
OTD 5.14.w	Testing Program for Valve with Water Sensor for Storm Hardening	2014	open	$ 21,625		$ 21,625		
OTD 5.14.x	Atmospheric Corrosion / Leak Survey Considerations	2014	2014	$ 35,000		$ 35,000		
OTD 5.15.b	Roadmap for Enterprise Decision Support System	2015	open	$ 2,778			$ 2,500	
OTD 5.16.b	Alternative Caps for PE Service Tees Fusible Caps	2016	open	$ 5,620				
OTD 5.16.c	Piercing Tool Redevelopment Enhancement to Remove "Mole" from Small Excavations (12mo)	2016	open	$ 22,150				
OTD 5.16.d	Stopping Off LP Mains with No Excavation	2016	open	$ 19,982				
OTD 5.16.f	Improved Safe Excavation Productivity for Locating Buried Utilities	2016	open	$ 5,274				
OTD 5.16.g	Enhancement of the Dynamic Cone Penetrometer (DCP) Compaction Device	2016	open	$ 53,033				
OTD 6.a	Sustaining Membership Program - GTI (discontinued)	2003	2012	$ 152,000				$ 152,000
OTD 6.6.a	Keyhole Consortium - GTI	2006	2012	$ 100,000	$ 20,000		$ 20,000	$ 60,000
OTD 6.08.a	(GTI) Carbon Management Information Center	2008	ongoing	$ 65,000		$ 25,000	$ 25,000	
OTD 6.11.a	PRCI Membership	2011	2015	$ 10,000		$ 10,000		
OTD 6.13.a	Quantitative Risk Assessment Methodology Protocol for LNG Facilities Siting (AGA)	2013	open	$ -	$ (10,000)	$ 10,000		
OTD 6.14.a	Quality Audit Program	2014	open	$ 40,000		$ 20,000	$ 20,000	
OTD 7.8.a	Pipeline Quality Biomethane: Guidance Document for Landfill and Water Treatment Conversion	2008	2012	$ 65,990				$ 65,990
OTD 7.9.c	Assessing Acceptable Siloxane Concentrations in Boimethane	2009	2012	$ 52,972				$ 52,972
OTD 7.9.d and 7.10.c	Improving Methane Emission Estimates for NG Distribution Companies, Phase 1 and 2	2009	2014	$ 67,674				$ 67,674
OTD 7.10a	Trace Constituents in Natural Gas	2010	2013	$ 78,205				$ 78,205
OTD 7.10.b	Odor Fade (GTI)	2010	2014	$ 36,940				$ 36,940
OTD 7.10.b Refund	7.10.b Refund	2010		$ (1,570)			$ (1,570)	
OTD 7.10.b.2	Odor Fade Phase 2 (GTI)	2010	2014	$ -		$ (10,000)	$ 10,000	
OTD 7.10.c Refund	7.10.c Refund	2010					$ (43)	
OTD 7.10.c.2	Improving Methane Emission Estimates for NG Distribution Companies, Phase 2	2010	2014	$ 67,674				$ 67,674
OTD 7.10.c.3	Improving Methane Emission Estimates Phase III - Cast Iron and Unprotected Steel Pipes	2010	2014	$ 99,839	$ 50,000	$ 49,839		
OTD 7.10.c.4	Improving Methane Emission Estimates for Natural Gas Distribution Companies Phase IV	2010	2014	$ 6,880		$ 5,000	$ 1,880	
OTD 7.11.a	Gas Quality Resource Center	2011	2013	$ 65,000	$ 20,000	$ 20,000		$ 25,000
OTD 7.11.a.2	Gas Quality Resource Center	2011	2013	$ 20,000			$ 20,000	
OTD 7.11.b	Trace Constituents Sensors	2011	2014	$ 27,610				$ 27,610
OTD 7.14.a	Next Generation Water Clean-up Technology Phase 1	2014	open	$ 25,000		$ 25,000		
OTD 7.15.a	Real Time Gas Quality Sensor	2015	open	$ 4,981			$ 2,500	
OTD 7.15.b.2	Remote Gas Sensing and Monitoring Phase 2	2015	open	3000				
OTD 7.16.a	Leak Repair Prioritization	2016	open	20110				
OTD 7.16.b	Evaluate Gas Imaging Technologies for LDC Applications	2016	open	30000				
OTD 7.16.c	Secure Communication for Networked Gas Sensors	2016	open	21302				
OTD 8.16.a	Intelligent Field Data Collection Platforms	2016	open	19956				
OTD 8.16.b	Remote QA/QC: Fusion Inspection and Reporting	2016	open	39441				
OTD 9.16.a	Determining Data Quality Implication	2016	open	56224				
OTD 9.16.b	Establishing Risk Tolerance	2016	open	25358				
				$ 6,229,580	$ 838,371	$ 834,690	$ 802,024	$ 2,520,240
T759	Ergonomic Study to Develop New Needle Bar	2005	2012	$ 29,889		$ 557		$ 25,366
T763	Rock Impingement	2007	2011	$ 19,250				$ 21,100
T764	Auto Gas Lamp Evaluation	2009	2012	$ 27,500		$ 10,443		$ 10,314