TRENCHLESS

FOR GAS INFRASTRUCTURE

NASTT NORTHEAST REGIONAL CHAPTER

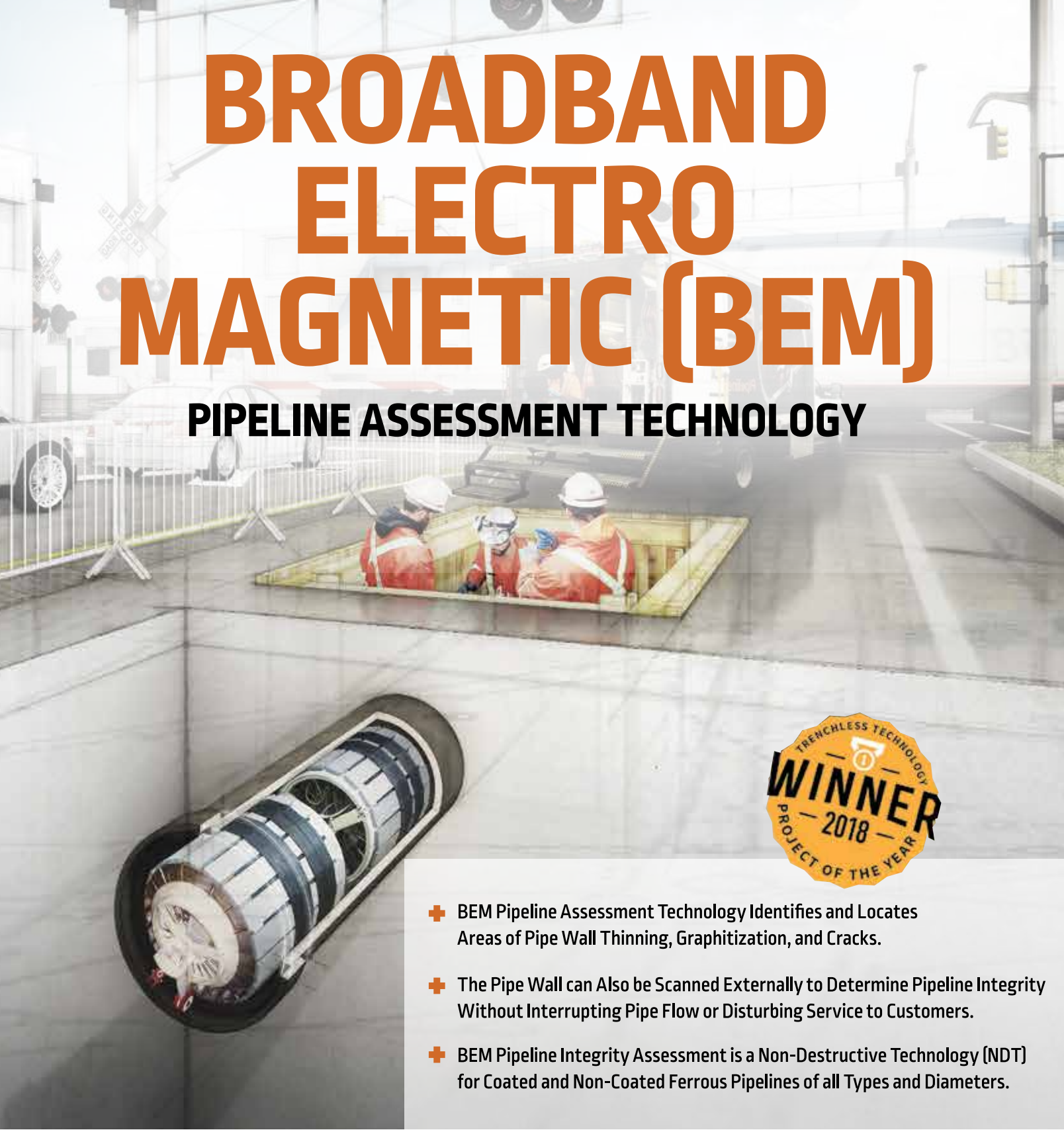
2021

DOE ARPA-E REPAIR Program Update

Rapid Encapsulation of Pipelines Avoiding Intensive Replacement

BROADBAND ELECTRO MAGNETIC (BEM)

PIPELINE ASSESSMENT TECHNOLOGY



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DOE ARPA-E "REPAIR" Program Update

Details on the Department of Energy's Advanced Research Agency– Energy (ARPA-E) 3-year, $38M research program called REPAIR (Rapid Encapsulation of Pipelines to Avoid Intensive Replacement) to rehabilitate cast iron, wrought iron, and bare steel natural gas distribution pipes.

Formidable Pipe Geometry Overcome with First-Ever Breakthroughs

A seriously leaking 36x30-inch reducer and 30-inch gate valve were buried amidst a dense maze of subsurface utilities and inaccessible to repair by excavation. Performing a liner inversion through such a unique configuration required several creative first-ever technical advancements for CIPL.

Risk Management Inspection (RMI ™)

As a popular technique to install gas distribution infrastructure, Horizontal Directional Drilling (HDD) can have a high relative risk of delays and potential failure. This article explores active and passive risk management approaches on HDD new installation and replacement programs.

The Future is Bright for Vacuum Excavators

Part III of the series on Vacuum Excavation Technology looks ahead to a very very bright future for the entire industry. Though long established as a go-to application for gas distribution infrastructure, a major growth opportunity for vacuum excavation is in the electrical utility market.

ALSO:

Departments:

TRENCHLESS TECHNOLOGY PERSPECTIVE

Bridging the Gap between Innovation and Implementation

George Ragula, RagulaTech Inc.

Welcome to the third annual edition of the NASTT-NE publication ***Trenchless for Gas Infrastructure 2021***, which highlights cutting edge trenchless technologies and feature articles demonstrating the efficacy, cost savings, and social and environmental benefits of using trenchless methods in underground construction programs. In fact, trenchless applications offer the best and most comprehensive toolbox of new installation, renewal and rehabilitation techniques for gas distribution infrastructure and is the fastest growing sector of the construction industry.

With over 50 percent of a utility's budget generally spent on construction, trenchless technology methods provide utilities the means to better serve customers more reliably and effectively at lower cost. Trenchless applications offer the gas industry huge benefits including enhanced safety, reduced excavations, reduced equipment emissions, smaller equipment footprints, reductions in 3rd party damage, and greatly minimized environmental and social impacts, including greatly reduced GHG emissions. Climate change is one of the most urgent issues for the United States with utilities focused on clean energy and a reduction in GHG emissions. Trenchless technology offers a solution to challenging projects requiring innovative approaches. Over time the technology has evolved so that the most complex and challenging projects are where trenchless really shines, reaping the greatest benefits and cost savings.

As shown in these pages, the development of leading edge trenchless technology applications hinges on both fundamental scientific research and from innovative responses to challenges encountered during construction. Tackling and completing progressively more challenging projects with greater complexity, diameters and distance creates a dynamic process, driving forwards continuous improvement to equipment, materials, processes and techniques. Expanding horizons provide the spark and impetus for ongoing investments in research and development. Innovations from leading edge technological research and development lead to further advances in the field, completing what is truly a "virtuous circle"! No wonder trenchless has advanced at the rapid pace it has since its early beginnings in the 70s.

Key to this dynamic process, and linchpin of these efforts, is the ability to bridge the gap between innovations in the laboratory and ultimately successful implementation in the field. Moving R&D concepts and efforts into proven workable technologies in the ground requires industry champions willing to incur the risks necessary to push new technologies to the outer limits. Rather than a clearly defined sharp boundary, successful commercialization of new technologies from research into the marketplace is more like the passing of a baton in a relay race. For an extended period of time, as innovations move from lab into field, both complementary halves must be in sync, running stride for stride to ensure a seamless transfer without ever dropping the baton!

Organizations such as NASTT, GTI and the AGA serve as catalysts for this process, because education and training are the keys to successful implementation and are staunch pillars to build upon. It is exciting to see the benefits and advantages the gas industry can potentially achieve through the use of these construction techniques at the right time and on the right job,

"We are passionate in what we do and how we do it."

but one needs to be more knowledgeable in this area and that is simply done through education and training – exactly what these organizations do for their membership.

My 43-year career in the natural gas industry was fortified by my 33-year career in trenchless thru my NASTT involvement. NASTT has the networking structure in place, so that even if you don't know the answer, you have the ability to know where to go to get it. The members of this organization are truly the leaders of the trenchless industry, and as such, work very closely and personally together in a "family" environment due to our common cause. We are passionate in what we do and how we do it.

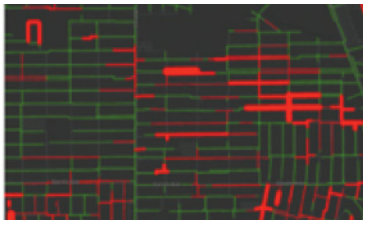
The ever-changing landscape of trenchless is constantly improving, and NASTT is committed to maintaining a critical focus on the transfer of technology and innovations successfully into the field. To some degree, utilizing trenchless methods requires thinking outside of the box in solving today's construction issues and pressing social and environmental challenges.

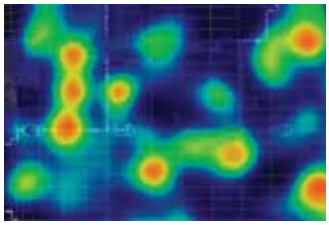
Special acknowledgement to the NASTT-NE Chapter, and its forward-thinking members and leadership, for sponsoring this magazine. We appreciate their continued support of outreach efforts to the natural gas industry.

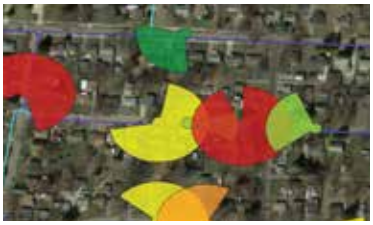
George Ragula

George Ragula, RagulaTech LLC
NASTT Hall of Fame Member

Hardware-enabled Software Solutions for Gas Distribution Operators







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WELCOME MESSAGE FROM NASTT-NE CHAIR

Babs Marquis, CCM, NASTT-NE Chair

Welcome to the 2021 edition of the NASTT Northeast Regional Chapter's ***Trenchless for Gas Infrastructure*** Journal. This edition features an update on the important DOE ARPA-E REPAIR research program (Rapid Encapsulation of Pipelines Avoiding Intensive Replacement) bringing to the market the next generation of technologies to rehabilitate cast iron, wrought iron, and bare steel natural gas distribution pipes. In addition, there are a variety of informative articles on trenchless applications in the gas industry, including the most complex CIPL lining ever attempted, risk management, condition assessments and testing.

Considering the global pandemic and how we have adapted to overcome the challenges we faced since the last publication, this edition highlights some of the opportunities and technical advancements in the gas infrastructure portion of the trenchless industry. With several vaccines now in play, the tide is changing, and the future is looking bright, and we are poised to meet the challenges ahead with vigor, innovation, and optimism.

In response to the lock-down and ban on traveling and cancellation of large gathering events over that past year, the National Board of Directors and NASTT-NE Regional Chapter, in concert with volunteer member involvement, the society evolved and adapted in various ways to keep our members engaged. The hard work is paying off as NASTT kicked off the year with 2021 hybrid In-Person and On-Demand No-Dig Show in Orlando, FL March 28 – 31, with enhanced COVID-19 protocols with great success. Continuing the momentum on the success of the national vaccination agenda, the Northeast Regional Chapter is looking forward to a Grand 2021 Regional Trenchless Technology Conference scheduled to be held November 15-16 at the historic West Point Military Academy in New York.

While we were initially disappointed to have cancelled our 2020 5th annual Trenchless Technology Conference in November at the elegant Portland Sheraton at Sable Oaks in Portland Maine, I am pleased to report that we are continuing our goal to expand awareness of trenchless technology throughout our region with an increased presence in Maine. For that reason, the Board has secured the venue and is continuing with planning arrangements for our 2022 annual event at the same venue!

We are continuing to work with our UMass Lowell student chapter to schedule virtual guest lectures for this academic year and returning to in-person lectures in September for the 2021 – 2022 academic year as well as restoring trenchless project site visits. We continue to solicit input from our regional trenchless practitioners to get involved in continuing with this endeavor as we see it as a forward-looking investment in the future of our industry.

Conducting the business of this chapter (especially hosting our annual conferences, publication of this journal as well sponsorship for our student chapter scholarship) would not be possible without the generous support of our sponsors and vendors. We extend our sincere gratitude for your continued support, participation, and investment to sustain the chapter. I hope the time you spend reviewing the articles and information in this our third edition of "Trenchless for Gas Infrastructure" will encourage you to get involved in the chapter, perhaps with an article or advertisement for the next publication, or a presentation focused on trenchless application for gas related projects at the 2021 Conference in NY. The Northeast Chapter is a strong voice for trenchless in the region, and we need your support to ensure the Chapter's continued success and growth in its mission and membership.

> *"Our safety comes first!"*

Thank you to all our members for getting involved and sharing ideas that contributed to the Northeast Chapter getting through pandemic and thanks to our current Executive Committee, and Board of Directors for your time and dedication during this difficult period. A note of thanks and appreciation to George Ragula for his continued dedication and collaboration with A to B Publishing in seeing Trenchless for Gas Infrastructure through to 3rd edition of the publication. Please visit our website at **https://talk-trenchless.nastt.org/northeast/home** for the latest information, registration and hotel details.

Babs Marquis

Babs Marquis, CCM,
Chair, NASTT-NE

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WELCOME MESSAGE FROM NASTT-NE CHAIR

Alan Goodman, NASTT-NE Chair

Natural Gas is a critical part of our infrastructure to meet the demands for a dependable and cost-effective source of energy. We've seen over the past year, much of the world came to a stop from Covid-19, while the construction and utility industries moved forward. Now more than ever, the demand for energy continues to increase. Natural gas continues to provide a safe and reliable solution, however the pipes carrying this energy source will need to be maintained or replaced as they meet their life expectancy. A recent example of our dependency on power and natural gas was made evident in February when over 4 million people experienced life without power and water in some of the coldest days in Texas. It is in those times that we realize how much we take for granted when we turn on the lights, get a glass of water or look up something on the internet. This is why our underground infrastructure is very complex and a crucial component of modern society. The needs of North America's underground services continue to expand as existing infrastructure reaches the end of its lifecycle. This is where the innovation of trenchless technology comes in.

Easements and right of ways are filling up with other pipes leaving little to no room for additional utilities or the replacement of those utilities due to congestion. Trenchless Technology is the obvious choice for underground infrastructure management when considering the installation, replacement, or renewal of underground utilities with minimal or no excavation and surface disruption. Innovative methods have been utilized successfully for all underground utilities including water mains, storm and sanitary sewers, gas main, electrical and fiber optics conduits. When employed in urban areas, substantial benefits are realized including dramatically reduced disruption to vehicular and pedestrian traffic, business activities, residential areas, and environmentally sensitive areas. In most cases, trenchless techniques will demonstrate significant cost saving benefits for municipalities and utilities over traditional open trench methods. Recent advancements in robotics have allowed trenchless technologies to provide pipe condition diagnostics never before available permitting utility owners to more accurately identify infrastructure priorities.

> *"Much of the world came to a stop from Covid-19, while the construction and utility industries moved forward."*

NASTT proudly represents municipalities and utilities, consultants and engineers, manufacturers and suppliers, trenchless contractors, and academia. Over the next few years, you will continue to see courses and training events that focus on the trenchless gas industry. We are proud to support 11 Regional Chapters and 18 Student Chapters. We attempt to reach out to all these groups to broadcast the latest trenchless advancements especially through our continuing education opportunities. The many benefits of trenchless solutions for today's infrastructure challenges will always be our strength.

Alan Goodman

Chair, NASTT Board of Directors

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DOE ARPA-E REPAIR PROGRAM UPDATE:

Rapid Encapsulation of Pipelines Avoiding Intensive Replacement

By: Jack Lewnard, DOE ARPA-E

The Department of Energy's Advanced Research Agency–Energy (ARPA-E) has kicked off a 3-year, $38M research program called REPAIR to rehabilitate cast iron, wrought iron, and bare steel natural gas distribution pipes. The goal of the program is to use robots to create a new pipe inside the old pipe. For the program to be successful, the new pipe must meet utilities' and regulatory agencies' requirements, have a minimum life of 50 years, and possess sufficient material properties to operate throughout its service life without relying on the exterior pipe. Considering that gas utilities have transitioned from town (coal) gas to natural gas in the past, we want to ensure the new pipes are compatible with potential gas compositions in the future, which may include renewable options such as hydrogen. And we want to do all this at a cost of less than $1 million per mile.

Using robots inside the pipes enables the creation of 3D maps from both the inside and the surface. The maps can integrate geospatial information for natural gas pipes and adjacent underground infrastructure with integrity, leak, and coating deposition data. These enhanced maps will facilitate maintenance planning and support 811 (national "Call before You Dig") call centers.

If the program sounds ambitious, that makes it a good fit for ARPA-E. Modeled after DARPA, ARPA-E funds development and commercialization of technologies that have high impact but may be too risky to attract private sector funding. The goal is to ensure that U.S. companies maintain a leading position in energy-related technologies. REPAIR, like many ARPA-E programs, pulls in diverse teams whose expertise often comes from outside the target industry. As discussed below, REPAIR teams are leveraging advances in chemistry, material science, robotics, and mapping—which originally were developed for the defense, aerospace, and automotive industries, among others. To ensure we "translate" these advances to the needs of the gas utilities, ARPA-E established the Testing and Technical Specifications Panel (TTSP) to advise the REPAIR program. The TTSP members include the Department of Transportation's Pipeline and Hazardous Materials Safety Administration representatives; state regulators and their association, the National Association of Pipeline State Regulators; representatives from gas utilities; and ARPA-E. Operations Technology Development, a collaborative research organization for gas utilities, is facilitating TTSP meetings.

"If the program sounds ambitious, that makes it a good fit for ARPA-E."

The REPAIR program is supporting three categories of work. The team led by the University of Colorado Boulder is developing the tests and performance metrics to ensure the "pipe in pipe" rehabilitation and inspection technologies meet expectations for regulators and gas utilities. We have seven teams working a wide range of coating materials, coating deposition tools, and integrity/inspection tools. Carnegie Mellon University is mapping pipes from the inside, while White River leverages its DOD-developed technology to map pipes and other underground infrastructure from the surface.

REPAIR Teams:

1. **University of Colorado, Boulder**
2. **General Electric Global Research**
3. **Autonomic Materials**
4. **University of Delaware Center for Composite Materials**
5. **Oak Ridge National Laboratory**
6. **University of Maryland**
7. **University of Pittsburgh**
8. **ULC Technologies**
9. **Carnegie Mellon University**
10. **White River Technologies**

Contact information for the REPAIR Teams and ARPA-E are available at https://arpa-e.energy.gov/technologies/programs/repair-0. We look forward to working with the gas distribution industry, *Trenchless for Gas Infrastructure*, and the North American Society for Trenchless Technology (NASTT) members on updates to the program and encourage you to reach out to the teams.

Testing and Analysis of Pipeline Encapsulation Technologies

The REPAIR program aims to define acceptable performance criteria for pipe-in-pipe (PIP) technologies specific to the gas industry and establish a testing and modeling framework to assess/validate technology performance. Researchers at the Center for Infrastructure, Energy, and Space Testing (CIEST) at the University of Colorado Boulder are leading the Testing & Analysis (T&A) team to evaluate technology performance and validate the 50-year design life for PIP trenchless system renewal. The team combines subject matter experts from the University of Colorado Boulder (CUB), Cornell University, Gas Technology Institute (GTI), and University of Southern Queensland (USQ) in Australia, leveraging extensive experience with the gas industry, physical testing and numerical modeling of infrastructure systems, and timely delivery of complex projects.

The methodology to assess PIP design life includes defining potential failure mechanisms and developing numerical, analytical, and physical testing protocols to investigate performance. Attributes of each method will be merged to deliver a comprehensive, data-driven assessment framework for PIP technologies that involve a variety of materials and deposition methods. The T&A team will characterize failure modes and establish performance criteria for pipe replacement technologies to support recommendations for PIP material properties suitable for acceptable design-life performance.

Full-scale test specimens and experimental protocols are designed to assess PIP performance under worst-case service loading conditions. Large-scale experimental facilities at CIEST at CU Boulder (Figure 2), and at Geotechnical Lifelines Testing Facility at Cornell (Figure 3), will perform full-scale external loading tests on pressurized, 12-inch diameter specimens simulating the effect of traffic-induced vibrations, lateral deflections, transverse ovalization, temperature-induced axial deformation, and adherence between the coating/pipe interface.

GTI will use its extensive laboratory facilities to conduct internal load tests on similar specimens simulating the effects of

University of Colorado Boulder

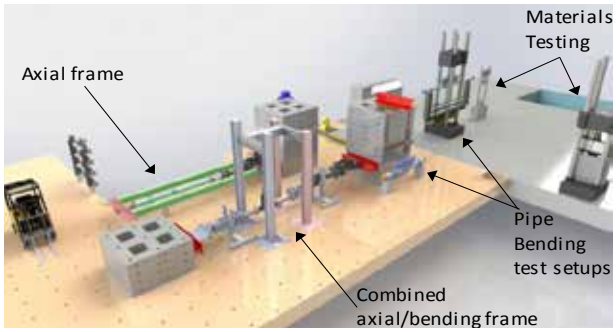


Figure 1. CUB CIEST structural dynamics and materials testing facilities with four current test setups capable of simultaneous pipeline testing

hydrostatic burst pressure, long-term cyclic pressure, full-scale leakage and permeability, and environmental durability (Figure 4). USQ will determine the required material characteristics of suitable PIP technologies using analytical models and 3D finite element analysis for correlation and extrapolation of failure mechanisms with physical testing.

The T&A team's efforts will culminate in an ecosystem for testing and analytical modeling of innovative products to enhance the performance/longevity of existing natural gas pipelines. The team will develop the assessment framework into standards and protocols to define a path for acceptance of REPAIR technologies as well as future innovative renewal methods. While the immediate goal is to support development for the natural gas industry, the T&A team sees significant opportunities for these trenchless technologies and validation methods to support innovation in other infrastructure sectors, including potable, waste, and stormwater systems. All reports, test protocols, and software tools from this work will be publicly available.

Figure 2. Physical testing of pipe infrastructure at CUB CIEST

Figure 3. Geotechnical lifelines testing facility at Cornell University

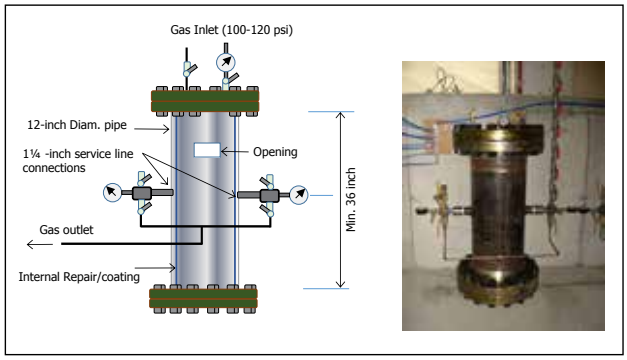


Figure 4. Setup of gas leak/disbondment tests at GTI

Pipeline Lifetime Upgrade with Trenchless Operation (PLUTO)

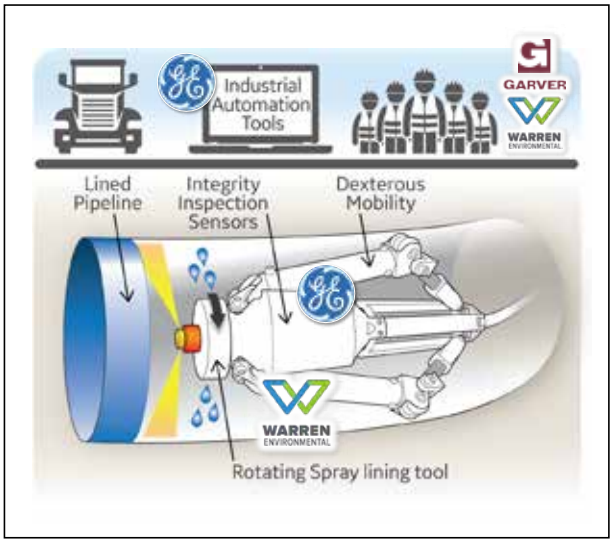
GE Research, Warren Environmental and Garver, LLC are collaborating to develop *PipeLine Underground Trenchless Overhaul* (PLUTO). PLUTO is a long-distance minimally invasive pipe repair system that will structurally rehabilitate gas pipelines at unprecedented speed at a significantly reduced cost compared with traditional open-cut excavation replacement.

The overall system consists of specially developed robotic positioning and deposition tools, lining materials, and pre- and-post-lining inspection tools. The guiding principles of the PLUTO system include excavating as little as possible to rapidly form the equivalent of a new pipe within an existing pipe, using the interior of existing pipes as molds. The system will rehabilitate a pipeline segment by following these steps:

1. Pipe ingress, overall pipeline health inspection and surface preparation for a small number of strategic locations
2. Withdrawing from the pipe while depositing lining material
3. Performing post-lining inspection to verify lining quality

A dexterous robotic crawler system will carry inspection, surface preparation, and lining tools into pipelines. Traditionally, as a system travels farther into a pipe, the weight and drag forces from the tether become too large to manage. To enable long-range operations, the PLUTO system distributes a train of tether manager crawlers along the tether to help overcome tether drag and boost material transport. Materials will be spin-cast in one thick coat to create a new, inner pipe with an expected service life of 75 years. Warren Environmental has developed proven materials for the water and fuel vessel lining domains that serve as an advanced starting point for the lining of gas pipelines. Smart material additives are being identified that allow sensors to better "see" the applied material thickness and help to locate potential defects over the renewed pipeline's life.

Pre-lining inspection will use white-light video and infrared imaging to map features and defects of the pipe, allowing a disposition to be made regarding pipe maintenance: return to service as-is, rehabilitate using the PLUTO system, or remediate using traditional techniques. Post-lining inspection will use the same sensors to detect defects that are expected to limit the life of applied linings. Computer vision techniques that automatically analyze inspection information will speed up the timeline to understanding the health of a given pipe.



As part of the ARPA-E REPAIR program, PLUTO system technical development is being accelerated to the point where we expect a field demonstration in late 2023. In parallel to this development, the PLUTO team is exploring the applicability of these trenchless technologies to adjacent domains. A key factor in successfully fielding such a pipe rehabilitation system is acceptance from pipeline owners and regulatory agencies, who are being engaged early in the development process. Commercial pipeline rehabilitation efforts are expected to commence as early as 2025 through Garney Construction, the parent company of Warren Environmental, supported by the PLUTO team. To deliver the best possible solution, the PLUTO team welcomes new partnerships with infrastructure owners and technical contributors in the areas of mobility, localization, inspection, and material development.

A Next Generation Trenchless Rehabilitation Solution for Legacy Natural Gas Pipes

Autonomic Materials, Inc. has assembled a team to develop a rehabilitation solution aimed at eliminating costly pipe excavation and restoration/replacement while minimizing gas service disruptions. To ensure longevity and integrity management, our solution will also leverage self-healing and self-reporting functionalities as well as pre- and post-rehabilitation inspection tools.

Solutions aimed at minimizing the cost of rehabilitating natural gas pipes must eliminate or significantly minimize excavation, which significantly contributes to current replacement costs. By definition, eliminating excavation requires a "trenchless" solution.

Our trenchless rehabilitation solution for legacy natural gas piping entails a novel Extruded-in-Place Pipe-in-Pipe (ExiPiP™) approach. This solution leverages a novel frontally cured poly(dicyclopentadiene) as the new pipe material. Frontal polymerization of dicyclopentadiene (DCPD) to form poly-(DCPD) exhibits a number of features that facilitate the deployment and functionality of the new pipe. Two of the most essential for the ExiPiP™ solution include:

(1) With the application of minimal heat energy, the DCPD resin formulation can be converted from a liquid or gel to a cured pipe with excellent mechanical properties in a matter of a few seconds following extrusion within an existing pipe;

(2) Frontally cured poly(DCPD) has been shown to exhibit a fracture toughness of more than three times that of oven-cured bisphenol-A epoxy and comparable Young's moduli and tensile strengths (Nature 2018, 557, 223 – 227). An extruded poly(DCPD) proof-of-concept pipe cured by frontal polymerization is shown in Figure 1A.

Given the mechanical properties discussed above, the pipe is unlikely to be damaged. In the event of damage, embedded microencapsulated healing and reporting agents will be released, repairing mechanical damage as well as highlighting it as an area of focus for maintenance (Figure 1B). The new pipe material will be deployed in a live pipe by a modular robotic platform capable of incorporating pre- and post-inspection tools as well as a deposition tool for extruding and curing the new pipe material. Data acquired in pre- and post-maintenance inspections will provide valuable information for more effective integrity management of the new pipe.

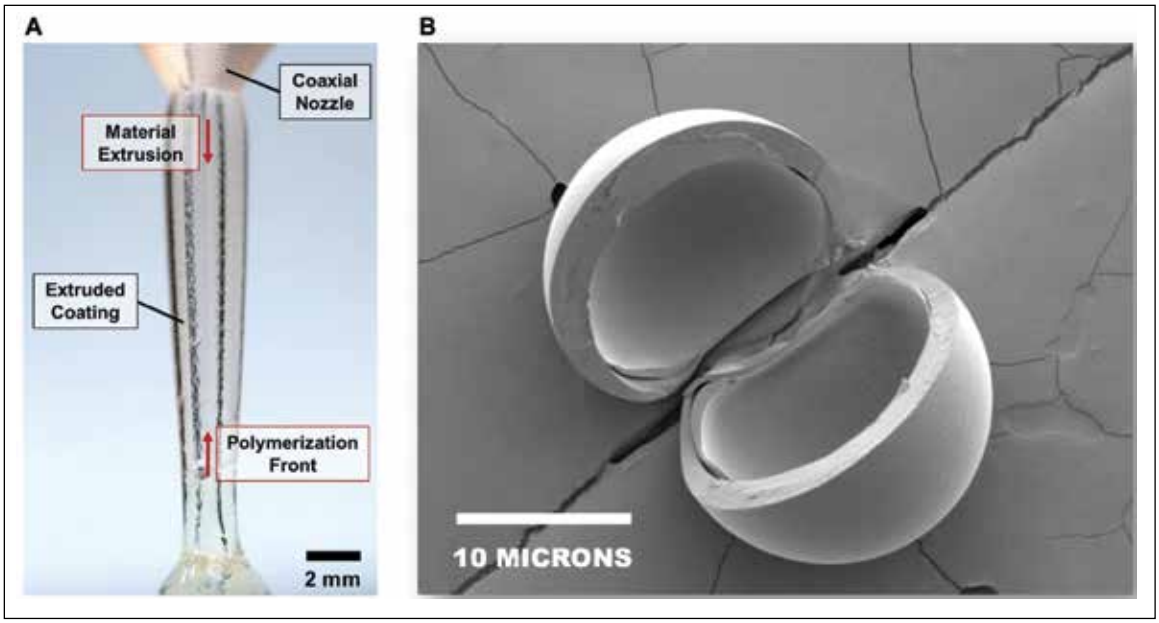
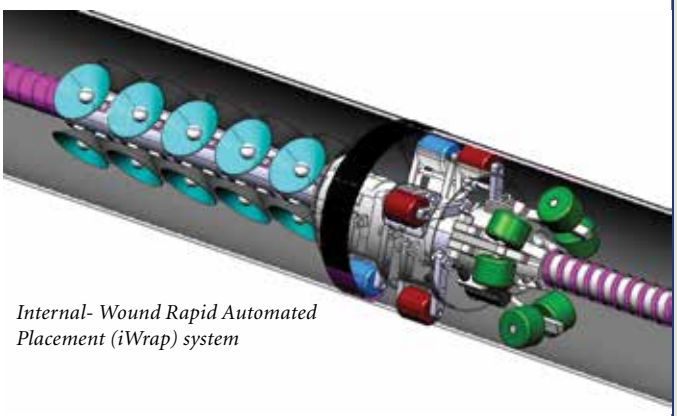


Figure 1. Proof of concept extrusion of poly(DCPD) pipe via frontal polymerization (A); and ruptured microcapsule following release of contents that we envision to be a healing agent or reporting agent

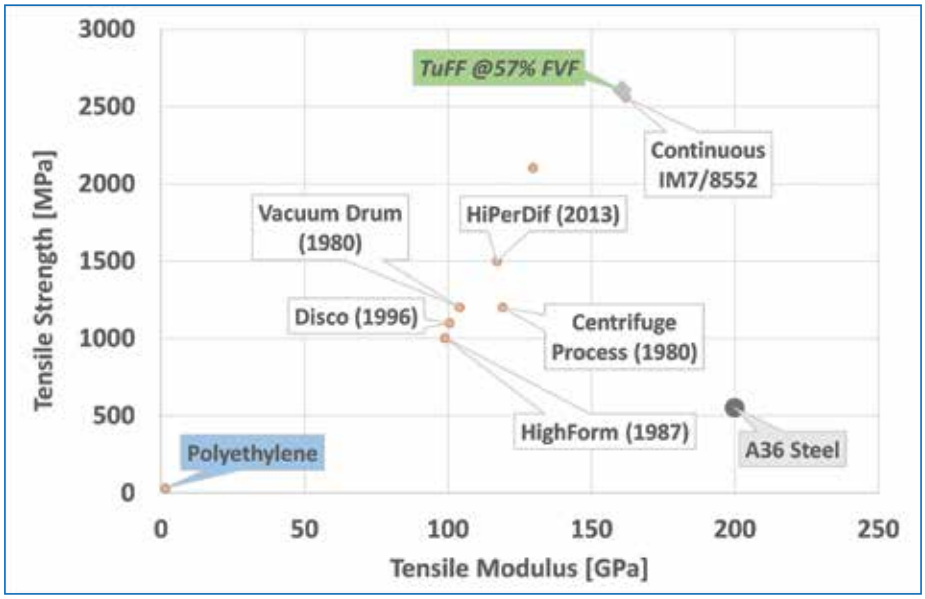
TuFF internal WRAP for Rapid Pipeline Repair (iWRAP)

The University of Delaware – Center for Composite Materials (UD-CCM) and Plitzie Inc. are developing a novel composite material feedstock and robotic placement process to inspect and fabricate stand-alone structural pipe within existing legacy pipelines—with no disruption in gas service.The solution, called the internal Wound Rapid Automated Placement (iWRAP) system, delivers and places new high stiffness-strength composite multi-layer feedstock inside existing legacy pipeline. The team will develop repair strategies for straight and slightly curved pipe sections, which will be internally wrapped and repaired using a new robotic-based design system to provide continuous placement of the material. A tethered material feeding system supplies material continuously; iWRAP places it in the pipe and UV-cures it. The use of low-cost, high- performance, and highly conformable feedstock based on the aligned short fiber called *TuFF* (Tailorable universal Feedstock for Forming) material is a key innovation. *TuFF* provides equivalent properties to continuous fiber composites and is the world's highest performance short fiber composite. TuFF provides in-plane stretchability approaching 50 percent strain and is highly conformable for fabricating complex pipe geometries and transitions. For example, high-performance TuFF feedstock based on an affordable E-Glass short fiber can reduce pipe wall thicknesses for a 12-inch diameter pipe by an order of magnitude compared with high density polyethylene replacement pipe solutions. Additional iWRAP system benefits include reduced material weight, which improves delivery capacity enabling longer pipe repair distances, and reduced placement time and installation costs overall. The system also enables custom wall thickness placement for localized repair and pipe loading conditions. In summary, this technology will revolutionize the pipeline repair industry using a cost-effective high-performance material with a non-disruptive innovative lining technology.



Internal- Wound Rapid Automated Placement (iWrap) system

High performance TuFF composite feedstock



TuFF properties far exceed polypropylene, A36 steel, and existing short fiber composite materials

Structural Materials-aided Advanced Renewal Technology for REPAIR (SMART REPAIR)

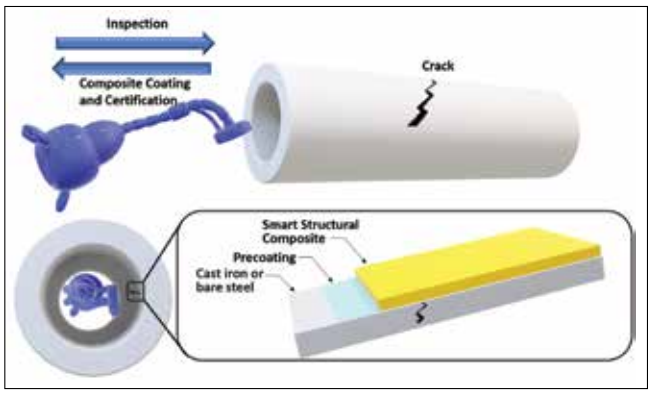


Figure 1. Rapid encapsulation of gas pipelines via a robotic tool equipped with the deposition of advanced fiber composite formulation and in-situ inspection and diagnosis

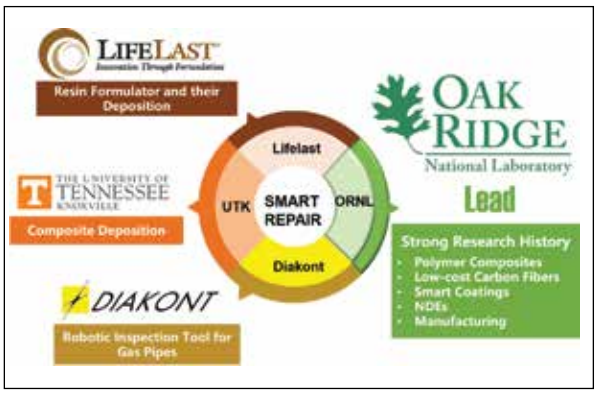


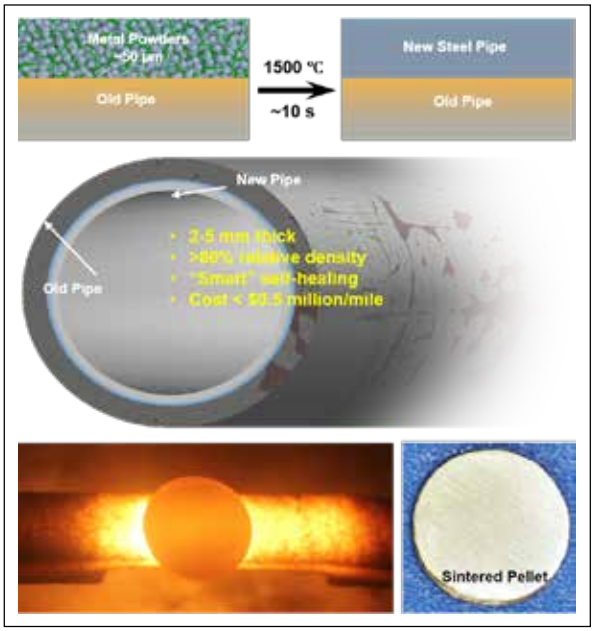
Figure 2. Complementary expertise of each institute enables a complete solution for REPAIR

The team led by Oak Ridge National Laboratory will develop a smart structural composite lining and inspection technologies coupled with a robust structural repair solution for gas distribution pipelines. This project aims to develop a cost-effective and highly efficient integrated structural lining deposition system and advanced high-end technology tools for inspection/validation (Figure 1). The team (Figure 2) will leverage Oak Ridge National Laboratory's success in developing low-cost carbon fibers, composites, smart polymer materials, and non-destructive evaluation methods; expertise of the University of Tennessee, Knoxville, on coating deposition; a partnership with LifeLast, an industrial resin formulation provider; and Diakont's expertise on robotic inspection tools (Figure 3) for gas pipes to deliver a smart repair solution and deployment. The designed polymer composite lining materials include resins and fibers to provide structural strength with the option of self-healing and self-sensing functionality. A robot will conduct pre- and post-inspection and deliver the structural lining materials inside existing to-be-repaired pipelines. One materials approach will consist of modifying epoxy and polyurethane systems to tune the cure times and temperatures as well as the rheological properties to provide a structural lining that can be deposited and cured in place without the need for external stimuli, such as heat or UV. Negating the need for external stimuli will enhance the safety of the process and enable this technology to be deployed in live gas pipelines. An additional differentiator will be the moving mold extrusion method that will be developed and implemented on 12-inch diameter metal pipes. Integrated robotic technologies for lining deposition and non-destructive multiscale interrogation of the pipe enable delivery of the complete solution for rehabilitation of gas distribution pipelines with the goal of less than $1 million per mile at full scale commercial implementation.

Figure 3. Deployment from a compact urban bell hole for a California utility

Pipe-in-Pipe by Rapid, Continuous, Smart Alloy Coating

The team led by the University of Maryland (UMD) together with the University of Pittsburgh, High-T Tech LLC., Diakont Inc., and Exelon Corporation will employ their patented high temperature sintering technology to rapidly sinter a steel coating layer in pipe-in-pipe configurations. This approach, which uses high temperature (~1500 Celsius) Joule heating, enables alloy powders to be sintered in ~10 seconds, limiting the "hot zone," and allowing compatibility with various pipes and gas environments without disrupting the gas service. The result is a structural steel pipe with high density and strength. The steel coating will be thinner (2 to 5 mm thickness is currently envisioned) than polymer composites due to its much higher mechanical strength, leading to a small impact on the gas flow and delivery capability.



The process of high temperature rapid sintering and its featured advantages

The assembled team utilizes the key expertise of each of its members. UMD and High-T Tech specialize in high-temperature sintering technologies, adapting them for use in an enclosed pipe environment and with metal powders that can be placed on the entire inner surface of the pipe. UMD also leads thermal and mechanical testing as well as thermal and mechanical modeling for pipe-in-pipe applications. The University of Pittsburgh leads the design of the metal powder to be used, including its composition and physical form (e.g., particle size, particle-size distribution). Diakont provides robotic systems for applying the metal powder in the pipe system, as well as the robotic application of the sintering tools within the pipe environment. Diakont has extensive experience with pipe applications and domain expertise. Exelon and its subsidiary BGE will provide distribution pipe samples, advise on application requirements and gas composition specifications, serve as the "voice of the final customer," and aid in commercialization efforts.

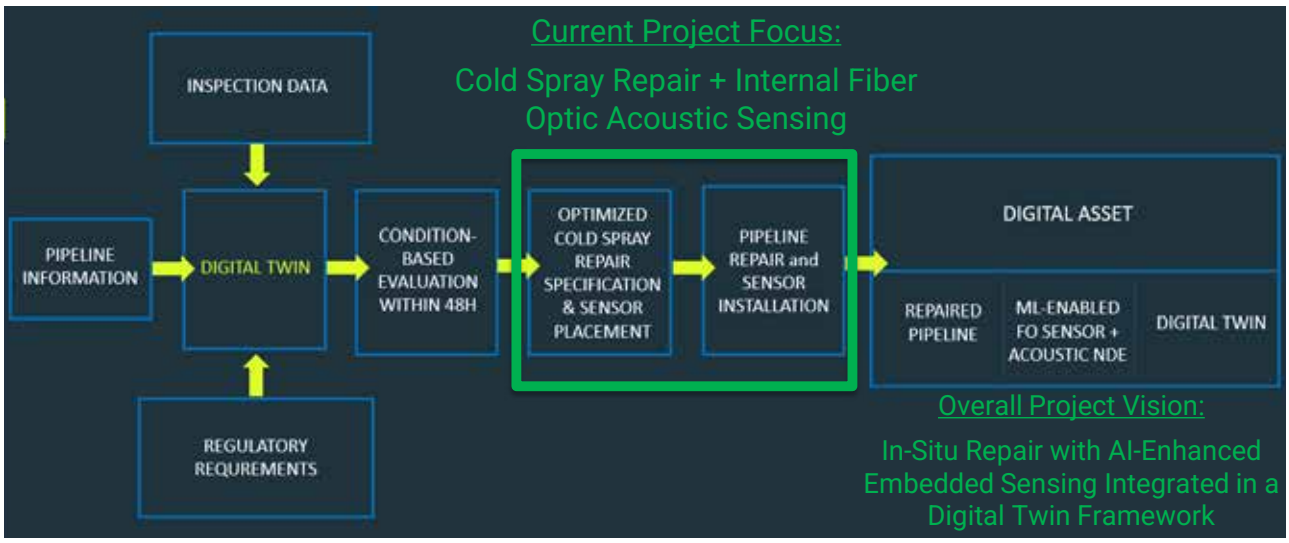
The team is committed to translating technical success to a commercial service. Commercialization of the metal powder formulation, materials, and aspects of the deposition process will be carried out by High-T Tech LLC, a spin-off company from UMD. High-T Tech LLC provides disruptive materials, science-based technologies, and solutions for energy- and sustainability-related applications, particularly in the fields of metal and ceramic membranes. The rapid sintering process also offers the potential to address additional market demands in water, wastewater, and oil & gas markets.

"Innervated" Pipelines: A New Technology Platform for In-Situ Repair and Embedded Intelligence

The team pursues a vision for in-situ repair and rehabilitation of pipelines with value-added embedded sensing to complement existing non-destructive evaluation (NDE) and in-line inspection. The team will demonstrate robotically deployable cold spray for producing metallic pipe within the original structure and explore feasibility of embedded fiber optic sensors within the newly constructed pipe. Acoustic NDE will be coupled with embedded fiber optic sensors and machine learning to identify, localize, and classify pipeline defects such as corrosion and other operational conditions of concern. Cold spray-based metallic coating offers a scalable, practical solution to confined space repair that is anticipated to satisfy regulatory requirements. Sensor embedding with cold spray repair combined with information from in-line inspections, mapping, and NDE in the context of artificial intelligence (AI)-based classification frameworks can reduce downtime associated with any future repairs required and also avoids costly, catastrophic failures. The team anticipates future additional efforts focused on robotic deployment strategies for cold spray rehabilitation and sensor embedding and integration of the AI-classification framework, new fiber optic sensors, and existing information in a digital twin model of the pipeline.

The University of Pittsburgh (Pitt) and Pacific Northwest National Laboratory (PNNL) are collaborating on this effort. Pitt has leading capabilities for designing, fabricating, and testing fiber optic sensors for pipelines, and extensive experience with fiber optic sensor embedding. Pitt also has extensive capabilities in multi-physics models and experience with AI-based data classification for development of a framework for automated localization and identification of defects and fault conditions within an operational pipeline. PNNL has extensive capabilities in acoustic NDE methods and cold spray repair. This team is complemented by an industry advisory team providing expertise in (1) robotic crawler development for cold spray repair and integrated fiber optic sensor deployment interior to pipelines, (2) regulatory and commercialization requirements for new pipeline technologies, and (3) digital twin model development and application.

Patented fiber optic sensor technology is ready for commercialization, with plans for a Pitt spin-off before ARPA-E REPAIR program completion. Commercialization of cold spray repair will also be pursued, and ongoing discussions are occurring with the industry advisory group. Long-term opportunities exist for an integrated service offering of the overall in-situ repair, integrated monitoring, and digital twin-based asset modeling for reduced cost of operation and rapid condition assessment. Early commercialization is expected in the municipal sector, with natural gas and other pipelines applications also of interest. Companies interested in collaborating on field validation and testing of new technologies and potential investors are encouraged to contact the project team.



Overall vision of "innervated pipelines", leveraging fiber optic sensors and AI, combined with cold spray-based metallic repair technology

Cold Spray Additive Manufacturing For New Pipeline Fabrication in Live, Natural Gas Distribution Mains

ULC Technologies is developing a novel Cold Spray Additive Manufacturing (CSAM) process for fabricating stainless steel (SS) pipes inside live, aging, gas distribution pipelines. Conventional CSAM processes have been extensively used for repair and remanufacturing applications in the aerospace, automotive, energy, and medical industries. The process employs a nozzle and heated, pressurized gas (usually nitrogen or helium) to accelerate metal particles to supersonic speeds and form a layer on top of a substrate.

ULC's novel CSAM process will instead use methane gas, which will offer compatibility with the operating environment inside natural gas distribution pipelines, enabling live pipeline rehabilitation with zero service disruptions. ULC's innovative design will repackage CSAM process equipment into a compact robotic system that can operate at high speeds. Since the process requires no pipe pre-cleaning, pipeline operators can restore pipe integrity quickly and cost effectively.

The superior properties of SS offer corrosion resistance, compatibility with standard pipe fittings, and low permeability to hydrogen for future hydrogen transport. By creating a freestanding pipe structure of high strength, the newly fabricated SS pipe will have minimal reliance on the aging host pipe substrate and offer a life greater than 50 years.

Bringing more than 20 years of experience in robotics R&D and Robotics-as-a-Service (RaaS), ULC will build a test facility to develop the CSAM process with methane gas and develop the robotic system. Dr. Farah Singer, Principal Investigator (PI), and Dr. Baiyang Ren, Co-PI, lead the development of the CSAM facility and process which will be completed during the first year of the project. ULC's partner, Penn State University Cold Spray Lab (PSU CSL), is a frontrunner in developing cold spray solutions and has performed extensive R&D for the U.S. Navy. The PSU team is developing the process parameters and optimizing the choice of SS material through characterization. The teams are also working with Brookhaven National Laboratory (BNL), a lab renowned for excelling at the design and operation of large-scale, cutting-edge research facilities. BNL will test cold sprayed samples and characterize the physical and mechanical properties of the deposited material.

In 2023, ULC will complete the development of the early robotic CSAM prototype. By late 2026, ULC plans to offer robotic services to rehabilitate live, carbon steel, and cast-iron natural gas pipelines (outer diameter ≥10 inches). The service will also provide inspection for both the host and newly fabricated pipes for commissioning and mapping purposes.

ULC's robotic CSAM process for rehabilitating aging gas distribution pipelines will reduce excavation costs, eliminate the need for hazardous waste disposal, and reduce methane emissions into the atmosphere. It will enhance energy delivery reliability and avoid disruption of gas customers' service while creating new manufacturing jobs.

ULC is interested in partnering with natural gas pipeline operators and others seeking to deploy the robotic CSAM technology for rehabilitation applications and welcomes any inquiries.

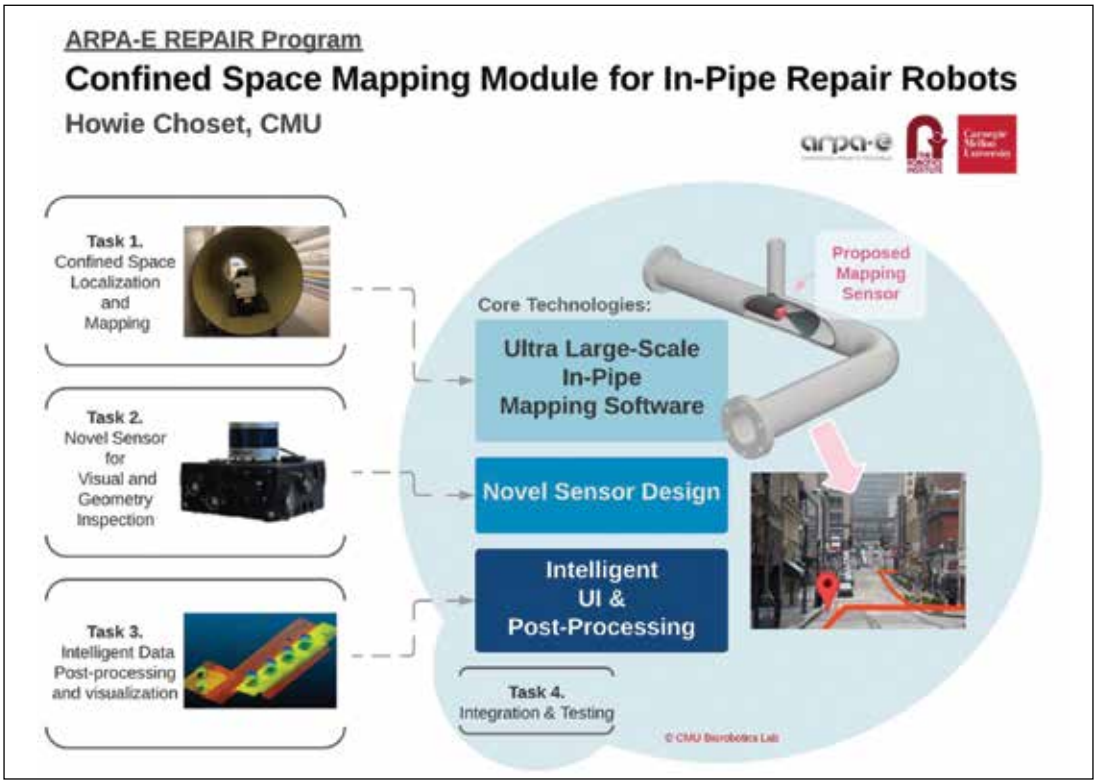
A simplified rendering of the CSAM process concept for fabricating an SS pipe inside an aging pipe

Confined Space Mapping Module for In-Pipe Repair Robots

Carnegie Mellon University (CMU) is developing a general-purpose mapping system that can integrate with virtually any mobile robot dedicated to pipe inspection and repairs. Confined spaces, such as inside small pipes, challenge map creation because they limit sensor payload size. This not only affects the choice of sensors, but how mapping system information is processed because of the space required to store computing infrastructures. On top of that, confined spaces challenge the use of the sensors themselves; most sensors have a lower limit on sensing range, which is often disrupted in small spaces. Finally, pipe-confined spaces lack obvious features, making mapping quite difficult. The team's approach (1) fuses data from multiple sensory sources to accurately and reliably map the structure of a large-scale, distributed pipe structure while gathering information on its health, (2) creates a novel sensor payload specifically designed to operate in confined spaces to provide visual and geometric inspection, and (3) takes in and manipulates large-scale point cloud data in computationally efficient ways to improve visualization and the opportunity for modern AI techniques to provide post-processing support.

The goal of the project is to develop easy-to-integrate tools to rapidly deploy the next-generation inspection and service machinery into pipes to expedite and reduce the cost of repairs. This automation will come in the form of a mobile robot moving through the pipes collecting sensory data and effecting repairs. Naturally, such a robot will need to integrate sensory signals (Lidar, ultrasounds, eddy current, imaging, etc.) with advanced mobility systems to create in-pipe maps. These maps have great value, as field technicians and applications engineers require them to geospatially locate items of interest, such as anomalies, leaks, wall thickness, results of coating deposition tests, etc. Maps are also necessary for maintenance or diagnostics systems to be able to navigate to areas of interest that require localizing relative to the pipe network.

This approach will return comprehensive, high-fidelity pipeline maps to utility owners. Utility owners will be able to check our returned maps against their pre-existing maps, correcting and updating them if necessary. Such a map-based system can diagnose problems in the pipe network that would be otherwise unforeseen and undetectable by humans. Moreover, the maps will provide an invaluable resource to the utilities, as our maps can be referenced with high precision to perform additional repairs on the pipelines, well after one repair has taken place. This precision will be crucial in preventing future accidents related to digging and excavation near gas pipes, and will save time, money, and lives by preventing accidents. The outcome of this project will enable system integrators to develop a mobile robot solution for in-pipe operations and create accurate 3D and feature maps.



New and Innovative 3D Mapping Technology to Enable Natural Gas Pipe Rehabilitation

Over the past two decades, new and innovative surface-deployed geophysical survey and mapping technologies have been developed to fully exploit electromagnetic (EM) methods. One technique is referred to as controlled-source, large-standoff, time-domain electromagnetics. That long name essentially describes high-tech metal detectors. The U.S. Department of Defense bet heavily on this technology, investing several hundred million dollars in perfecting EM methods to detect, locate, and classify unexploded ordnance (UXO).

ARPA-E's REPAIR performer White River Technologies (WRT) is a leader in the field of controlled-source electromagnetics. Located in New Hampshire, WRT scientists and engineers developed several versions of this military technology for UXO, IED, and landmine applications. Over the last 5 years, WRT modified their core technology for shallow marine settings deployed via crawlers in the surf zone or via remotely operated vehicles (ROVs) for seabed location and identification of fiber optic cables. Additionally, WRT configured their "APEX" technology for civil infrastructure applications.

For ARPA-E's REPAIR program, APEX will address two challenges. First, APEX will provide reliable, near real-time XYZ locations of buried natural gas pipes up to 3 meters deep. Unlike ground-penetrating radar (GPR), APEX uses a controllable transmitter technology that can shape and envelop a subsurface target with EM energy. A companion to these transmitters is a sophisticated array of 3D receivers, housed within APEX, that measures the detailed responses to subsurface energized targets. This process reveals accurate 3D locations as well as critical target "fingerprints," from which we classify each buried item. Further, unlike GPR, APEX is largely unaffected by soil conditions—and completely functional in the presence of water.

Second, the transmitter and receiver elements of APEX will be separated, and the transmitters repackaged to fit inside the REPAIR pipes. Mounted on REPAIR robots, these "in-pipe beacons" will allow APEX surface receivers to pinpoint the robot location. As the in-pipe beacon moves through a pipe, APEX will map the 3D centerline of the pipe and the location of the REPAIR robot. w

By leveraging two decades of work for the military, APEX will provide utilities and service contractors with key capabilities to detect and locate pipes with unmatched accuracy, at greater depths, and with greater reliability than ever before.

ABOUT THE AUTHOR:

Dr. Jack Lewnard *is a Program Director at the Advanced Research Projects Agency-Energy (ARPAE). His focus at ARPA-E is on methane production, distribution, and use. Lewnard joined ARPA-E from Chesapeake Utilities Corporation where he was Vice President of business development. There, he was responsible for identifying and developing new business opportunities in natural gas, alternative fuels, combined heat and power systems, and renewable energy. Before Chesapeake, Lewnard was Vice President and Chief Technology Officer at the Gas Technology Institute (GTI) where he led the Office of Technology and Innovation. In that role, he directed the development and implementation of the company's technical strategy and vision and managed the internal research and development program.*

Lewnard earned a B.S. in Chemical Engineering from the University of Cincinnati and a Ph.D. in Chemical Engineering from the University of California, Berkeley.

Updating the Natural Gas Infrastructure

Retrofitting Aging Cast Iron and Bare Steel Gas Pipelines

To continue to bring natural gas safely and efficiently to market, it is vital to maintain and modernize critical delivery infrastructure. The Advanced Research Projects Agency-Energy (ARPA-E) REPAIR program is focused on enhancing the performance and longevity of natural gas distribution systems by developing technologies to address leaks from legacy and outdated natural gas pipes and working to reduce costs per mile by 10x to 20x.

A suite of technologies to enable the automated construction of new robust pipes inside of existing pipes is being created, offering retrofits to rehabilitate the existing system.

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GTI is playing an important role in the $5.4 million evaluation and testing portion of the program being led by the University of Colorado at Boulder. Working with other partners Cornell University and the University of Southern Queensland, the team will test and analyze pipeline encapsulation technologies that can meet utility and regulatory requirements.

The multi-institutional team will develop a comprehensive data-driven framework of physical testing and modeling to enable the gas industry to better evaluate products it uses to rehabilitate aging cast iron and steel natural gas pipelines.

The objective is to validate a 50-year design life for innovative pipe-in-pipe (PIP) systems by developing numerical, analytical, and physical testing protocols. The effort will focus on pinpointing when pipes are likely to fail, characterizing failure modes, and establishing performance criteria for pipe replacements to support recommendations for suitable PIP material properties.

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Operations Technology Development (OTD), a stand-alone 501 c (6) non-profit, is managing the Testing and Technical Specifications Panel (TTSP) for the program. OTD has assembled a team of industry professionals that will provide critical expertise to validate the technologies for industry use and acceptance. Participants from utility companies, state and federal regulatory bodies, research organizations, standards organizations, gas industry organizations, and other groups will provide input and guidance to ARPA-E and performers to help overcome both operational and regulatory hurdles to enable broad industry adoption.

Formidable Pipe Geometry Overcome with First-Ever Breakthrough Innovations

Technical Advancements Expand a Comprehensive CIPL Toolbox for Gas Pipe Repair and Rehabilitation

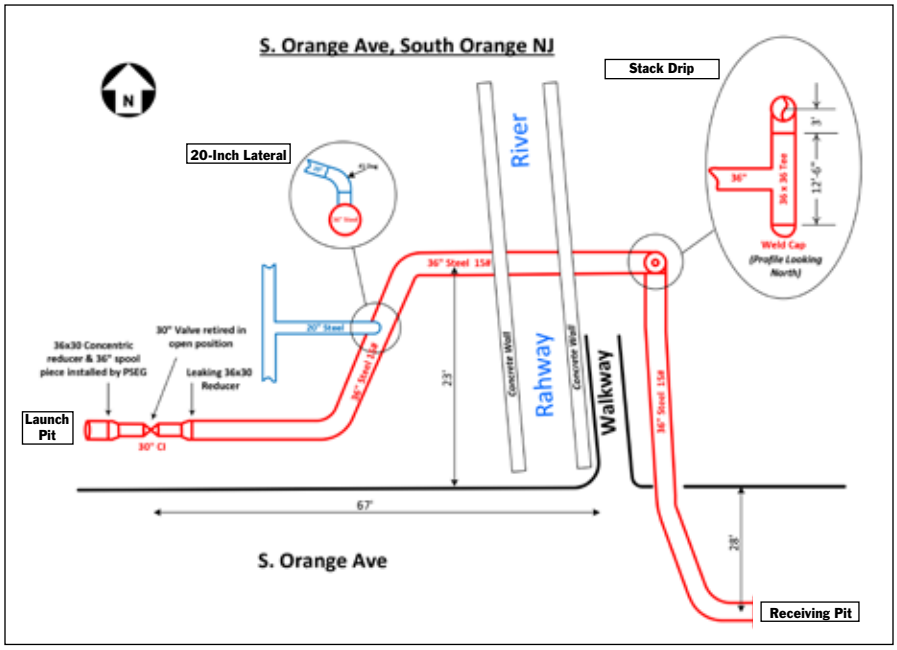
By: George Ragula, RagulaTech LLC

WHAT A MESS!

On our first Zoom-call project meeting, when I described the situation to the contractor, and outlined my game plan for what we needed to do, at first there was complete stunned silence. Not a word uttered by anyone. So silent you could almost hear a surgical mask drop and hit the ground. It was May 2020, in the hot discontented Covid summer, and there was a major problem underground in South Orange NJ where the Rahway River crosses under South Orange Avenue. A big high pressure 15 psig leaking problem!

A 36x30-inch steel reducer connecting a 30-inch cast iron main to a short 165 LF segment of 36-inch steel pipe was leaking significantly at 15 psig. Buried over 10 feet deep amidst a dense maze of subsurface facilities, including a six-foot-wide telephone switching bank going to 8 feet deep, several monitoring well shafts arrayed like sentries around a decommissioned underground gasoline storage tank, and surrounded by the usual sewer, water and electrical subsurface nearby, this reducer and stretch of steel pipe were completely inaccessible to repair through ordinary excavation.

In addition, the pipe had extremely challenging geometry with 6 complicated bends, an opening for an active 20-inch steel lateral, and legacy drip riser stack assembly consisting of a steel 36x36-inch tee with one leg looking down. On the east side the pipe plunged from 5 feet quickly down to 15.5 feet in order to cross under the Rahway River, and then ascended sharply to 10 feet depth on the other side of the river to connect with an inaccessible 30-inch valve, and a run of 30-inch CI pipe stretching westwards. We quickly nicknamed this short but extremely challenging pipe configuration "The Mess".



Challenging complex geometry of "The Mess" was compounded and complicated with the dense inaccessible subsurface

Built in 1971 to cross under the Rahway River, when the river channel was being encased in concrete and the bridge widened, the formidable geometry presented by "The Mess" put everyone on edge. Though a very short run of only 175 LF, the six bends, compounded and complicated by the challenging 3 dimensional stack drip geometry, reducer and gate valve, presented the most compressed and complex set of obstacles any of us had ever encountered.

A temporary concrete cap with 2-inch vent line was placed as an interim repair to vent the leaking gas as a safety measure, however due to the high pressure and diameter, there was urgent need for a permanent solution. Because the 30-inch valve was impossible to remove by excavation, we had to find a way to push a 36-inch liner through a short section of 30-inch pipe, the 30-inch gate valve itself, and a 36x30 reducer before navigating six bends that included a stack drip and inverting through the remaining 165-foot length of 36-inch steel pipe.

Performing a liner inversion through such a unique and demanding configuration had

"It takes a talented team to make an engineer's dream come true!"

never been done before anywhere in gas, or any other CIPL application. Finding the best solutions tested our resourcefulness and ingenuity to the maximum. Utilizing trenchless methods requires thinking outside of the box, and "The Mess" took this notion to the greatest extreme possible. I always say "Plan, plan again, and over-plan." The time put into design and planning is certainly the tried and true way to cement progress and ensure success.

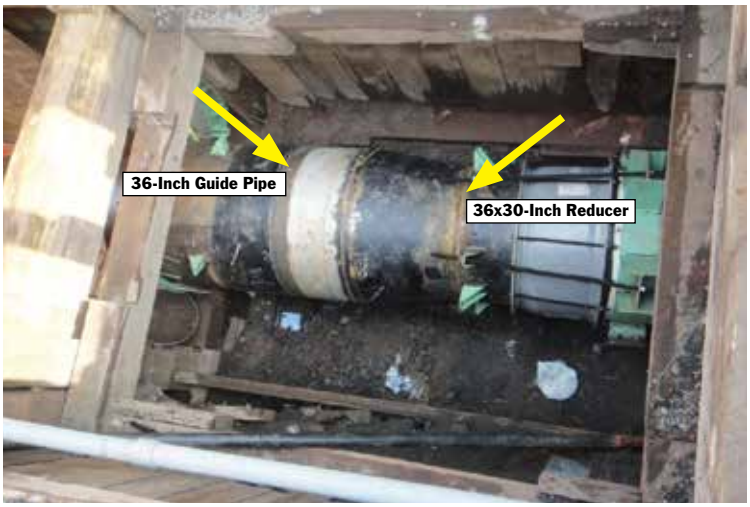
Surmounting the challenges presented by "The Mess" took a lot of creativity, innovation, and time invested in careful planning, design and preparation. Design engineering unique and very well thought out first-ever innovations and rigorous shop-testing prior to lining were keys to a successful liner inversion, and the foundations of our ultimate victory over the forbidding geometry of "The Mess".

CIPL TECHNICAL ADVANCEMENTS

The "Mess "was my final CIPL rehabilitation project with PSE&G, and the fitting apex to my lengthy career and extensive body of trenchless work performed in the utility world. CIPL rehabilitation of gas distribution pipelines has evolved a tremendously expanded range of capability over time, with the trenchless application now being used more frequently for progressively more challenging gas industry projects with increasing complexity, larger diameters and greater distances. CIPL has advanced to the point where the most complex and challenging gas projects are where lining technology really stands out, and delivers the greatest benefits and cost savings for a utility and its customers. I am extremely proud to have played a leading role in these many developments and innovations from the ground-floor level advancing to where we are today with the technology.

Project contractors Progressive Pipeline Management (PPM) have developed deep

36-inch Valve was excavated on the east side of the "The Mess" to form the Receiving Pit for liner inversion



CIPL lining through a 36-inch Guide Pipe, two 36x30-inch reducers, and a 30-inch gate valve has never been accomplished anywhere before

Pipe configuration of "The Mess" was built in 1971 when the Rahway River in South Orange NJ was encased in a concrete channel and the bridge widened

experience and valuable expertise in gas infrastructure construction over the course of many projects. Since 2002 PPM has been the exclusive North American installer of the Starline® liner product, which was developed specifically for renewing high pressure large diameter natural gas mains. The patented Starline® liner system has undergone ten years of rigorous testing with PHMSA, Cornell University, and NYSEARCH, demonstrating the potential for a 100+ year service lifespan after installation. The Starline® liner uses a specially formulated two-part epoxy to bond the liner to the host pipe, which is mixed onsite and applied to the liner just before inversion.

Fundamental to the success of this project was the experience and proficiency contractor PPM developed in lining progressively more challenging pipe configurations, including two world-record setting diameters, most recently the milestone 42-inch CI main lined under the Garden State Parkway in East Orange NJ, all of which required innovative planning, design and advancements. This high level of capability and track record of success, was crucial in being able to formulate innovations through design engineering in response to challenging field conditions backed by extensive shop testing at PPM. David Wickersham, PPM President and CEO, said, ***"The versatility and testing pedigree of the Starline liner, combined with our 19-years of installation experience, were invaluable to the successful rehabilitation of this difficult pipe configuration."***

36-inch Guide Pipe was essential to ensure 36-inch liner was aligned correctly as it traveled through the 30-inch segment

Advancements from solutions to challenges on previous projects have become regular practice on our CIPL work moving forwards. Innovations created from solutions to previous challenges, some first implemented only a year ago, have now become well established and are incorporated into standard practices on our gas industry CIPL projects. For example, curtain grouting was first used to stop water infiltration and intrusion (I&I) on an abandoned main in 2020 on the world record-setting CIPL of a 42-inch main in East Orange NJ. We did this again on "The Mess".

Unimaginable even a decade ago, what were once first-time innovations are now regular features on every CIPL gas installation. Along with six new breakthrough advancements detailed in this article, these previous technical advances were the basis for our most recent success on the "The Mess":

- automatic pressure monitoring while curing,
- expertise in custom fabricating SRS bridges over legacy gas fittings,
- curtain grouting to stop water inflow after a main is abandoned,
- optimizing vacuum systems while reducing equipment footprint size,
- redesigned liner inversion drum/cone/transport hose,
- self-propelled robotic sandblasting unit,
- dust collectors to recover grit,
- tail and catch-end reinforcement,

- heavy lubrication of retention strap to prevent liner chafing.

Every element of this previously acquired knowledge and expertise was crucially important to our success on "The Mess". Now, faced with the forbidding geometry of "The Mess", with little time left before the October 1 mandated gas-in date, additional new innovations were necessary in order to conquer the challenges presented by this unique and difficult pipe configuration. Design engineering and intensive shop tests were essential in support of six first-ever technical achievements used to overcome geometry on this project.

FIRST-EVER BREAKTHROUGH TECHNICAL ACHIEVEMENTS

Highlights of the major first-ever technical accomplishments that were essential for successfully CIPL lining "The Mess". The following new achievements have never been done on any CIPL project before, anywhere, with any CIPL application.

The fact these were done first on a gas distribution installation in the midst of the Covid-19 pandemic only adds to this impressive feat:

- First-ever installation of a 36-inch liner through two 36x30-Inch Reducers and a 30-Inch Gate Valve.
- First-ever use of a 36-Inch Guide Pipe to stabilize the liner before inversion through the first 36x30-inch reducer.
- First-ever design, fabrication, installation and removal of a temporary 20-Inch Metal Restraint Plug to cover a 20-inch lateral and provide a bearing surface for the liner inversion and pressure test
- First-ever use of High Strength Epoxy to fabricate a 90-degree bend from a 36x36-inch Tee that was part of a legacy stack drip fitting
- First-ever use of High Strength Epoxy to span an open 30-inch Valve Gate Well providing a bearing surface for the liner inversion
- First-ever use of High Strength Epoxy Spray to reinforce the leaking 36x30-inch reducer, completely coating the ID of the reducer prior to liner inversion.

Transport hose used to convey inverting liner down into 10-foot deep pit. This innovation eliminates chafing during liner entry and is referenced as the "US Method"

Extensive shop testing of the Guide Pipe and Reducer configuration ensured that the liner would traverse the obstacles and invert properly over the entire length of "The Mess"

"We are only limited by our imagination, progress is continuously unfolding."

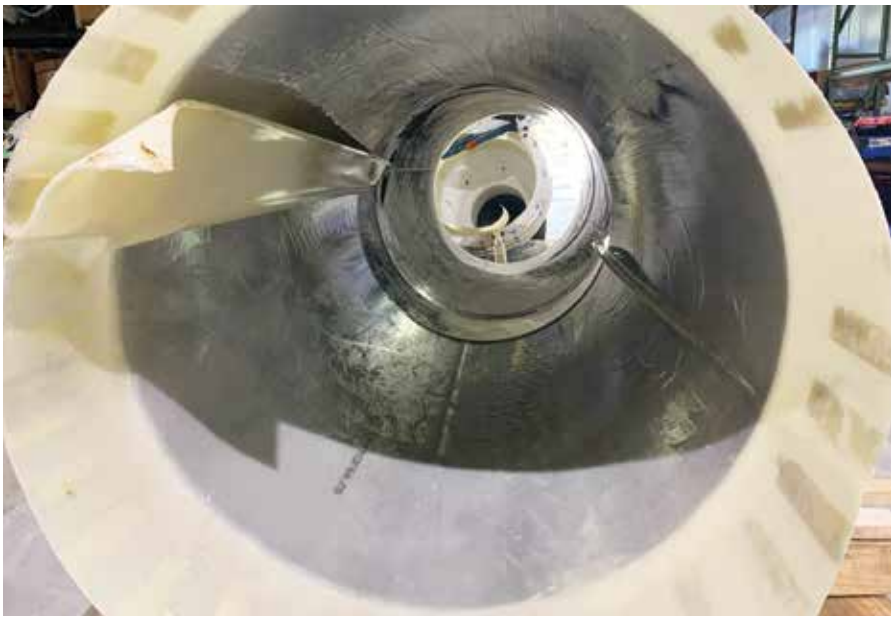
1. 36-Inch Lining through Two 36x30 Reducers & 30-Inch Gate Valve

Replacing the 30-inch gate valve and leaking 36x30-inch reducer via excavation was impossible due to heavy subsurface congestion. Because these fitting were connected to the section of 36-inch steel pipe just beyond that traveled under the Rahway River, it was necessary to push the liner through this short 30-inch section first before it could invert eastwards through the remaining 36-inch section of steel pipe.

A second 36x30-inch reducer was installed and connected to the 30-inch pipe upstream of the gate valve so that the 36-inch liner could enter the short 30-inch section. This is the first time ever a liner has been inverted through two reducers, in any CIPL application.

2. 36-Inch Guide Pipe & Shop Tests

For the first time ever, a 10-foot section of 36-inch guide pipe was attached to the first newly installed 36x30-inch reducer in order to ensure the 36-inch liner was aligned correctly upon entering the two reducers and gate valve, and to stabilize the liner bubble and minimize wrinkling of the liner as it inverted through the smaller diameter short 30-inch section.



Shop testing demonstrated the wrinkling would be minimal with Guide Pipe and Reducer in place

Before inversion, extensive shop testing was performed on the guide pipe and reducer configuration before it was installed. The tests confirmed that minimal wrinkles in the liner were structurally sound and did not create any breaches in the liner integrity. Correctly aligned by the guide pipe, the liner was able to invert properly throughout the entire length of 36-inch steel pipe after first traveling through the complicated 30-inch section. First time this has ever been done.

3. Temporary 20-Inch Restraint Plug

First-ever design and installation of a prefabricated metal temporary restraint plug used to plug-off a 20-inch diameter lateral located at a 13-foot depth that had to be subsequently reopened by cutting the liner back after a successful pressure test. This prefabricated restraint plug played a key role in providing a bearing surface to prevent liner rupture upon liner installation and pressure test. The liner was cut away, and the restraint plug removed entirely once the liner had cured in order to allow gas to flow up into the lateral. Prior to this work, a Miller Pipeline crew had used the opportunity to Weko-Seal the abandoned 20-inch lateral.

4. High Strength Epoxy Elbow

First-ever use of high-strength epoxy to fabricate a 90 –degree bend out of a 36x36-inch tee as part of a stack drip geometry to facilitate liner installation through the fitting. Normally this legacy fitting would

Design engineered prefabricated metal plug installed to cover a 20-inch lateral and provide bearing surface for liner inversion

have been replaced with a 90-degree elbow, however the fitting was 15.5 feet deep and located in an area containing monitoring wells due to prior gas station tank leaks.

We decided the best approach would be to use high-strength epoxy to fashion a 90-degree elbow from the 36x36-inch tee portion of this fitting. Stone aggregate and leftover sandblast grit were used to backfill the stack drip riser section up to the level of the 36-inch steel pipe, and then a mastic epoxy was manually spread on top of the fill to form a smooth congruent bearing surface for the liner.

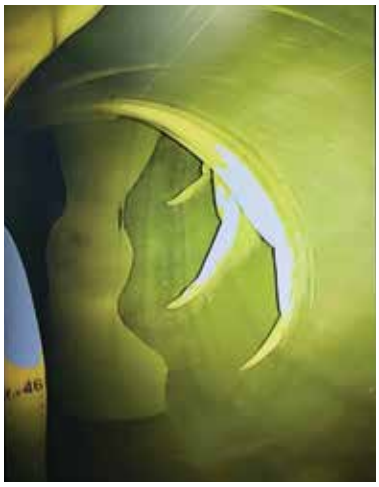
Fabricating a new 90-degree elbow for the first time from a legacy stack drip fitting using fill and high-strength epoxy is a first-ever breakthrough technique which will prove invaluable on many future gas industry CIPL projects.

5. Valve Gate Well Epoxy Bridge

Breakthrough uses of high-strength epoxy technology to support CIPL

Liner was cut away, plug removed and 20-inch lateral restored after curing

Application of high-strength heated epoxy spray to reinforce and seal leading 36x30-inch reducer was a breakthrough technical accomplishment



Elbow fabricated from high-strength epoxy was crucial in allowing liner to navigate compound curve with minimal wrinkling

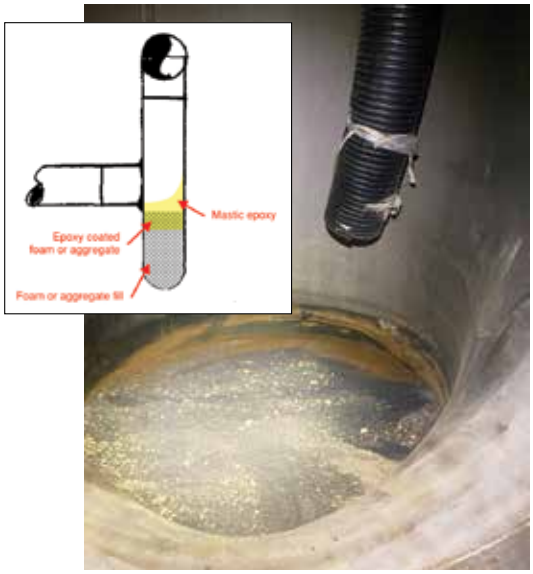
lining also included the first-ever use of this technology for filling the 6-inch wide 30-inch valve gate well in order to provide a bearing surface for the liner. The well was covered with a smooth surface of mastic epoxy.

6. Leaking Reducer Epoxy Spray

First-ever use of high-strength epoxy spray to reinforce a leaking 36x30-inch reducer by spraying a 0.25-inch layer of epoxy on the entire ID of the fitting prior to lining, to reinforce and add strength to the fitting, which was the final preparation necessary before inversion could begin. This first-ever breakthrough technique will prove invaluable on future gas industry CIPL projects.

DESIGN ENGINEERING INNOVATIONS: CONQUERING FORMIDABLE GEOMETRY

Like attaining a mountain summit, on Friday August 31, 2020 we conquered the forbidding geometry of "The Mess", overcoming daunting obstacles and successfully inverting the 36-inch liner through two 36x30-inch reducers and 30-inch valve, 6 bends, (four 90-degree, one 58-degree, one 22-degree), and two steep grade changes. It was a great deal of bending and shifting to go through for such a short 175-foot length of liner. After months in



Stack was backfilled, then covered with mastic epoxy to form a 90-degree elbow from the 36x36-inch Tee

Use of aggregate and mastic epoxy to bridge 30-inch valve gate well was done for the first time ever

Injected curtain grouting into the surrounding soil from the interior of the pipe was again used to prevent water entry into the depressurized main

design, and weeks of preparatory work both in the shop and onsite, the actual liner inversion took less than two hours.

While on the South Orange Ave site, we also opportunistically lined the two segments of pipe that were connected to either side of "The Mess" for a total of three inversions for the project. An 825 LF segment of 30-inch CI pipe was lined on the west side of the river, and then stretching eastwards from "The Mess", on the other side of the river, an 875 LF length of 36-inch CI. These final two linings were straightforward shots and did not entail any of the extraordinary preparation "The Mess" did.

Given the magnitude of the task, it was a mere two weeks before, on Monday August 17, that PPM moved onto the site and immediately began intensive preparations on a compressed schedule. Preliminary CCTV inspection runs were done the same day, and then curtain grouting to prevent water penetration into the abandoned main began immediately on Tuesday August 18, taking the rest of the week, until Friday August 21, to complete.

Using curtain grouting into the soil surrounding an abandoned main at depth to stop water intrusion was first used successfully in 2019 in preparation for the world record setting CIPL of the 42-inch CI main under the Garden State Parkway in East Orange. Curtain grouting is a great example of a breakthrough innovation becoming a regular important step in the process of preparing the pipe for lining, where there is a chance of water intrusion entering depressurized pipe. Injected curtain grouting guarantees a dry interior for sandblast cleaning the pipe, and ultimately ensures a smooth lining process by eliminating excessive moisture penetration, which is the primary cause of liner disbondment during inversion.

For "The Mess", confined space entry was again required to install the grout from the interior of the pipe. Extensive safety precautions were used including rescue harnesses, fresh air circulation, gas monitoring equipment and a confined space rescue team onsite. A body board and pulley system transported workers down into "The Mess", and then grout

Confined space entry with extensive safety precautions was necessary for several preparatory steps prior to lining

Dust collector with three 16-inch hoses was used to recover leftover cleaning grit

was injected into the soil surrounding the pipe by pumping it from the pipe interior through check valves in holes drilled into the pipe. The grout was allowed to cure over the weekend, and on Monday August 24 the excess grout was removed, and the check valves were ground flush with the inner pipe wall and filled flush with epoxy.

Cleaning began immediately on Monday, and, as with the use of curtain grouting, technical advancements first used during the cleaning phase in the world record 42-inch CIPL the previous year were an essential element in getting "The Mess" ready for lining. The dust collectors and 16-inch inlet hose configuration was used again and generated sufficient airflow to remove any grit leftover from the sandblast cleaning.

After the cleaning process was completed, the A&W Maintenance subcontractors moved onsite and completed bridging the gap of the gate valve well with high strength epoxy to provide a bearing surface for the liner, and also sprayed the interior of the leaking 36x30-inch reducer, as detailed above. The most critical part of their work involved the transformation of the stack drip tee to a 90 bend which had to be hand-troweled. The epoxy cured over the weekend, and the necessary lining of "The Mess" was completed on the following Monday, August 31.

Due to the tight complicated geometry within the short 175-foot length of pipe, there was substantial concern that the retention belt would chafe holes in the liner, especially at the furthest end of the alignment, where the liner inverted through the final three bends. This concern was addressed by making the retention belt as narrow as possible, and heavily lubricating it. As a result, there was no abrasion or any damage to the liner from the retention belt throughout the inversion.

Once the post-lining CCTV inspections were completed and pressure tested to 25 psig, and the restraint plug was removed from the 20-inch lateral, the repaired main was gassed-in Tuesday, September 29, just ahead of the October 1 outage deadline.

PPM SITE SERVICES & FIRST CALL PPE

It is important to point out that this extraordinarily difficult project was accomplished during the Covid-19 pandemic – adding to the extreme challenges we already faced with the inaccessible geometry were necessary strict site safety protocols, sanitation practices, and daily Covid-19 screenings for the crew as part of the regular daily site safety meetings.

Fortunately, two companies affiliated with project contractor PPM, PPM Site Services and First Call PPE, specialize in providing environmental cleanup and site sanitation services and supplying clients on industrial sites and gas utilities with high quality masks, PPE, rapid antigen tests and protective antimicrobial defense sprays. This expertise ensured zero Covid-19 cases during

Self-propelled robotic sandblast unit nicknamed "The Beast" was again used to clean the pipe interior before lining

the entire difficult and intricate six-week period of construction.

COMPREHENSIVE CIPL TOOLBOX!

With the successful repair of the very inaccessible pipe layout of "The Mess" nothing can stop us anymore in terms of geometry! Any needed fitting can be now fabricated using metal or high-strength epoxy and gaps over legacy fittings can be bridged using various structural reinforcement sleeves or prefabricated metal restraint plugs for the specific purpose at hand. Tackling and completing challenging projects like "The Mess" creates a dynamic process, driving forwards continuous improvement to equipment, materials, processes and techniques.

The first-ever technical advancements used to solve "The Mess" are crucial elements added to the CIPL toolbox. Through numerous gas rehabilitation CIPL projects tackling increasingly complex and difficult repair work, with ever greater diameters and distance, we have achieved mastery, assembling a significant body of work that now offers a comprehensive toolbox of approaches for repairs on any gas main, no matter the diameter, length, or configuration of the buried pipe. Responding to challenges presented by projects like "The Mess" are what drives creativity and innovation forwards. We are only limited by our imagination, progress is continuously unfolding.

CONCLUSION & REFLECTIONS

"The Mess" was the final CIPL project I did with PSE&G marking the apex of my career with the utility. Like climbing a mountain, it was an uphill battle against imposing geometry, only made possible with the ingenuity and clever technical innovations everyone brought to the table, and our numerous past successes. It takes a talented team to make an engineer's dream come true!

Dave Wickersham summarizes ***"Already having completed several award winning projects with George and PSE&G, we were up to the challenge when he approached***

Liner ambient cured with nitrogen supplied as make-up air

Covid-19 safety protocols were a daily routine onsite

It takes a talented team to make an engineer's dream come true

Liner with six tail bolts

us with his engineering design on this project."

Throughout my 43-year gas industry career, I have seen this natural upward progression of technical competence and prowess as various trenchless construction techniques move from theoretical considerations during planning into the realm of practical application in actual construction projects, and then followed by eventual improvement as experience is gained.

The real world experience acquired from completing underground construction projects using trenchless applications then gets filtered back into research and development, which in turn yields fresh innovations, improvements and ingenious new construction techniques. Networking, education, and sharing information are key drivers, providing focus and the foundation for this collective effort.

More than 33 years involvement in the North American Society for Trenchless Technology (NASTT) has allowed me to maintain an up to date awareness of trenchless technology methods and best practices, along with recent technological advancements. If I don't know the answer, I am confident I can find it through my NASTT peers. By being able to network among numerous industry experts on various underground construction applications/techniques at conferences, seminars and technical sessions, and with access to a rich storehouse of technical peer-reviewed technical papers, I have been exposed to numerous ideas that have enabled me to devise unique and cost-effective solutions to the challenges encountered on various gas construction projects over the years.

By accomplishing the near impossible in solving "The Mess", everything is now possible with CIPL for the repair and rehabilitation of gas distribution systems.

Inversion of the liner through "The Mess" took less than two hours

THE MESS = WINNER

"The supreme accomplishment is to blur the line between work and play"

(Arnold Toynbee)

ABOUT THE AUTHOR:

***George Ragula** is CEO and Founder of RagulaTech with over 43 years of experience in gas industry engineering, operations, construction, research/development/deployment and management. George is a noted authority on trenchless applications for the gas industry having spent 33 years specifically focused on trenchless. He received his B.S. in Mechanical Engineering from Polytechnic Institute of Brooklyn in New York. George is a past Chair of NASTT and serves on the NASTT No-Dig Show Program Committee. He also teaches several NASTT courses on various trenchless technology topics, including CIPL for the Gas Industry.*

Risk Management Inspection (RMI™): Managing Risks of Installation Failure and Schedule Delay

By: Jake Andresen, MS, P.E. Staheli Trenchless Consultants
Kimberlie Staheli, Ph.D, P.E. Staheli Trenchless Consultants

Trenchless construction of pipelines has a high relative risk of schedule delays and installation failure when compared to traditional open cut and cover installation. The primary factors that contribute to elevated risks with trenchless construction are a) the severe consequences of encountering unfavorable conditions and b) the uncertainty in the conditions which will be encountered.

Figure 1. Maxi-Sized HDD Installation

This article describes the application of Risk Management Inspections (RMI™) to horizontal directional drilling (HDD) used for the installation of gas infrastructure.

HORIZONTAL DIRECTIONAL DRILLING AND GAS INFRASTRUCTURE

HDD is a popular installation technique used in the gas industry to install infrastructure ranging from 1-inch service connections up to large diameter 24-inch and greater high pressure transmission mains. Many gas companies incorporate HDD into their new installation and replacement programs and HDD has served as an effective tool to complete installations beneath features (crossings) which would otherwise require challenging open-cut installations that would be extremely difficult to permit with regulating agencies. Examples of crossing types which are regularly seen on gas pipeline projects are railways, highways and roadways, culverts, rivers and ravines. Further HDD has been used to limit disturbance along the alignment for a number of reasons: compliance with environmental regulations, community goodwill, and expediting permitting processes.

While the technology applied to all of these examples is generally described as HDD, the alignment, methods, and risks on small PE services are vastly different from the methods and risks required for 6-to 8-inch high pressure gas main installation. Similarly, the risk profile increases dramatically when installing 24-inch diameter and greater, high pressure transmission mains.

RISKS INHERENT TO HDD

HDD has been established as a valuable pipeline installation tool, but it has both advantages and disadvantages. Some of the disadvantages are inherent to the trenchless nature and others are specific to HDD. One of the common concerns with the use of HDD is that techniques used to recover from a risk occurrence may eliminate the benefits of using the trenchless method that were envisioned during planning and design. Clear examples include excavation within a roadway to remove an obstructing particle or the release of large volumes of inadvertent drilling fluid returns spilling into sensitive environments. It is important to fully understand the risks and mitigation measures used to move the project forward should those risks occur as the benefits of using trenchless may be lost when excavation and disturbance is required to complete the project.

There are any number of approaches to risk management on HDD projects, however a common industry approach in the past has been to treat HDD as a catch-all solution for a given complex problem such as crossing a river or traversing a steep slope. This approach ultimately speaks to the development of HDD as a construction and need-driven technology. The ability and approach to risk management is often controlled by the contractor and dependent on their lessons-learned on previous projects,

which are not necessarily addressed in designs and bid packages. To effectively incorporate HDD into increasingly challenging and schedule driven contract packages, it is imperative for the owner to implement an active strategy to both identify and mitigate the site-specific risks.

ACTIVE VS. PASSIVE APPROACH TO RISK MANAGEMENT

The following situation illustrates a scenario that has occurred on many historical projects:

Background: HDD uses pressurized drilling fluid to assist in the excavation of the borehole and the removal of the excavated material from within the borehole. The drilling mud is mixed with the excavated soil and pumped to the ground surface through the borehole as the drill advances. One significant risk for HDD is the loss of drilling fluids during drilling or the loss of circulation within the borehole. When this occurs, there is a high likelihood that the excavated material will not be effectively removed from the borehole, resulting in excessive frictional loading on the pipe when it is pulled into the borehole. The excessive friction can result in the pipeline becoming stuck in the borehole. A stuck pipe may require any number of mitigation measures that typically include attempting to remove the installed pipe, re-drilling the existing borehole to remove excess material, or initiating a new borehole along a revised profile in an attempt to drill within more favorable geotechnical conditions.

Situation: A new transmission pipeline project that includes several miles of 30-inch steel pipe and includes HDD crossings has been awarded to a prime contractor. The prime contractor self-performs the open cut portions of the pipeline and hires HDD sub-contractors to install the specified crossings. Geotechnical information obtained by the Owner during design indicates that HDD is a feasible installation technique in the site soils. A project schedule has been developed to meet the Owners desired in-service date for the pipeline. The construction includes six river crossings of approximately 2,000LF each which are planned for installation using HDD.

The contractor mobilizes two HDD spreads to meet the in-service milestone date and the contract includes provisions for liquidated damages in the event of delays. The contractor follows industry-standard practices during drilling, however due to the geotechnical conditions and limited available temporary construction easement, the contractor has schedule delays placing the project in-service date at risk. The construction delays are due to low rates of drilling fluid returns during the pilot bore and reaming processes that results in excavated soil recovery that is well below the volume of the borehole. To minimize this risk, the contractor could initiate a swab pass to clean the borehole and remove any excess excavated material from the borehole; however, this will require an additional 1-2 days to complete.

Passive Risk Management Approach (Typical approach).

During the difficult drilling, there is some coordination between the contractor and inspector and the contractor is encouraged to follow the contract and meet their target completion dates while following best practices. The owner is notified that there may be some challenges achieving the target schedule and that the contractor is having drilling difficulty. Although the contractor is aware of practices that could reduce this risk, they are also aware of the schedule implications. As such, they elect to move forward without performing a swab pass due to the heavy consequence of schedule slippage. When the product pipe pullback is three-quarters complete, the product pipe becomes stuck within the borehole due to high frictional loading and cannot be advanced or pushed out by the drill rig.

After the risk associated with poor drilling returns manifests in the product pipe getting stuck, mitigation measures to remedy the situation are extensive in both cost and schedule slippage and range from removing the pipe and re-reaming the borehole for a second attempted pullback, to completely re-drilling the entire borehole along a difference profile to increase the probability of success. Schedule delay for these mitigation measure can range from 2 weeks to well over 2 months. The Owner has little input to risk mitigation response and there is likely to be a large change order submitted by the drilling sub-contractor to recover damages that they feel were attributed to the soil conditions.

Active Risk Management Approach

During construction of the bore, the inspector tracks the drilling fluid returns during the pilot bore and reaming passes

and notes any losses of drilling fluid. The inspector reviews the collected data in real time and notes the challenges associated with maintaining drilling fluid returns, and the drilling procedures used (or not used) to overcome the challenges of effectively cleaning the borehole. The Owner is notified of the issues early in the drilling process and is able to participate in discussions on procedures that could be implemented to increase the chances of a successful pull. The Owner is made aware of the benefits of a swab pass to reduce the risk of becoming stuck during pullback. The Owner can then have discussions with the inspector and the contractor regarding the cost and schedule impacts of implementing proactive risk measures to avoid the situation where the pipe becomes stuck during pullback. The Owner now can make a proactive, informed decision on implementing risk-saving measures that would avoid a potential costly claim. As a result of these discussions, the contractor performs the swab pass which is completed in one day. The torque and thrust data during the swab pass identify several areas of the bore that are not clean. An additional reaming/swab pass is performed to clean the bore and the product pipe is successfully pulled into the borehole. The drilling takes an additional week to complete; however, the cost impacts of getting a pipe stuck and fighting a change order or differing site conditions claim are eliminated.

Approach Analysis

In the passive approach, the Owner may be aware that there is a problem; however, they may not appreciate the risk that the contractor is taking to preserve schedule, nor may they be aware of the cost implications (and near certain change order) that they will be faced with in the event of a failed pullback. Risk mitigations and costs are not discussed until after the problem occurs leading to delays and cost over-runs. The Owner may be presented with a large change order once the problem is mitigated but may have no understanding of the events that led to these costs.

With the active approach, the real-time evaluation of key data is used to identify a problem and help the owner understand the risk implications. This arms the owner with the information needed to understand that by moving forward without swabbing the bore, they are exposed to a much greater risk (the pipe being stuck) and can take steps to determine if meeting the target deadline is worth the risk of significant cost overruns and even greater delays presented by a stuck pipe.

Most owners would likely agree that they would prefer 1 week of schedule delay compared to a pullback failure that requires several emergency construction meetings, quick decisions with limited construction records, and specialized equipment mobilized to the site. This is easy to see in hindsight but difficult to manage during construction without an established procedure for identifying risk. The goal of the active approach is to develop a strategy to: a) identify potential problems and record information needed to make rational decisions on risk management; and b) when emergencies occur, have the required records, combined with risk and mitigation tracking, so an informed rational decision can be made quickly with no delay to construction.

Risk Management Inspection (RMI™): Changing the Approach to Inspection to Minimize Claims

RMI is an active approach to trenchless construction risk tracking and management. It is often implemented most cost-effectively using 3rd party specialty inspectors on-site during the HDD construction because the HDD carries a disproportionately large amount of the overall project risk. RMI was developed by Staheli Trenchless Consultants based upon extensive experience negotiating post-construction damages from many projects that resulted in part from passive inspections. This experience led to the development of the RMI technique to minimize large schedule delays and cost over-runs.

The following example of Risk Management Inspection techniques illustrates the benefits of the active risk management approach to help the Owner understand and manage their risk exposure.

Active Risk Management Approach – Project Example

Background: The HDD pullback is arguably the construction activity that poses the greatest risk for the pipeline Owner. The pullback is completed at the end of the project when up to 90% of the required work (pilot bore, reaming passes and hole preparation, pipe assembly and staging) has been completed. These costs have been expended and potentially paid, but the Owner has no pipeline if the pullback fails. Further, a stuck pipe has the potential to contribute large schedule over-runs to the project, change orders, and potential claims.

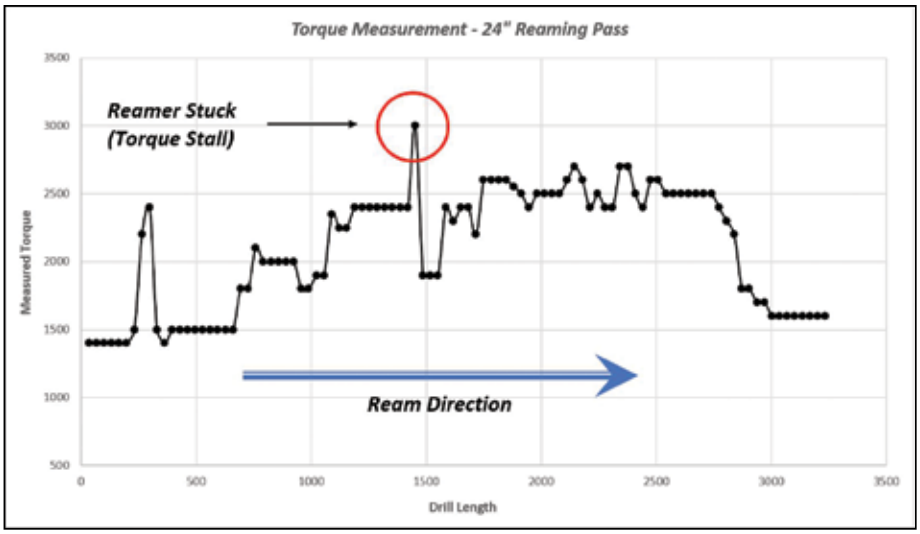


Figure 2. Torque pressure during 24-inch pull-ream

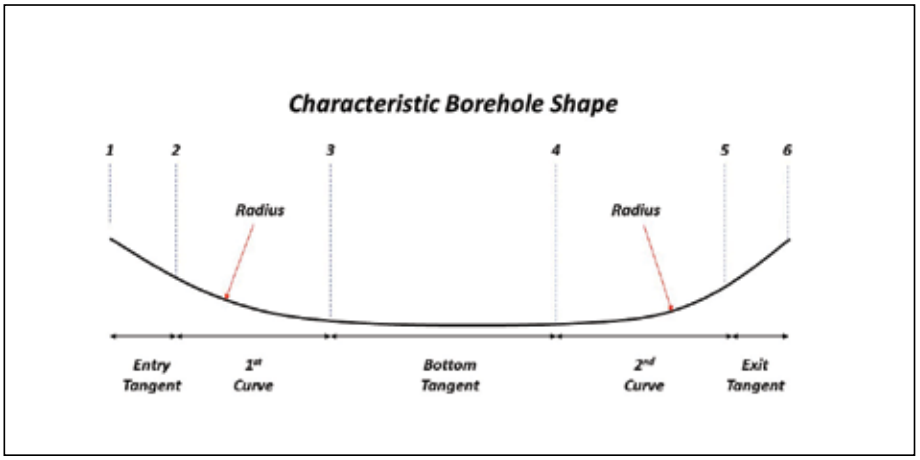


Figure 3. Characteristic Borehole Shape

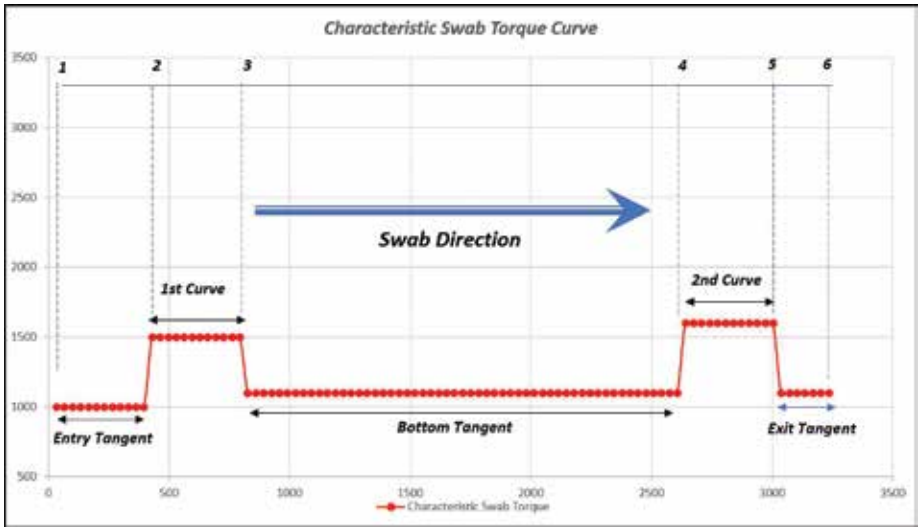


Figure 4. Characteristic Torque Curve During Swabbing

Torque is an important parameter to indicate whether the borehole is clean and ready for pullback. Data collected by a specialty trenchless inspector, including torque, thrust, penetration rate, and fluid pump rate, can be evaluated during the pilot and reaming processes to determine drilling behavior and borehole viability. This information can be used to compare data collected from the swab pass. Instrumentation readings collected during a swab are a strong indicator of whether the borehole is prepared for a successful pull-back.

On a challenging HDD project, the torque readings were analyzed during reaming and swabbing to determine if the borehole was properly prepared. This project consisted of the installation of a 16-inch steel pipeline coated with fusion bonded epoxy. The HDD length was 3,085LF and the borehole reamed to a 24-inch diameter. The geotechnical conditions were highly variable and consisted primarily of silty sand; however, seams of gravel and cobbles were encountered along the alignment. Figure 2 shows a graph of the torque readings that were recorded by the specialty inspector.

During the final reaming pass, the reamer became stuck at approximately 1,400 feet into the reaming pass and the 24-inch reamer could not be pushed or pulled by the drill rig alone. Using the tail string, the reamer was pulled back towards the exit to free the reamer. The pull ream was then continued toward the entry location once the reamer was free from the bound conditions.

Because circulation was lost and the reamer became stuck, the bore posed a high risk for the pullback to experience high pull loads or become stuck. As such, a swab pass was conducted to evaluate the condition of the borehole. A swab pass or proof pass consists of a barrel reamer that is pulled from one end of the bore path to the other. Because the swab pass is being run through previously excavated bore, the swab should record a lower torque than the final reaming pass at the same reaming rate.

Swab passes performed on relatively stable boreholes have a characteristic curve shape. Conceptual typical vertical bore path segments are shown in Figure 3 along with the corresponding characteristic swab measurements in Figure 4. The torque is low as the reamer enters into the borehole along the tangent section, shown in Figure 4 as the line from point 1 to point 2. As the swab passes through the first curved section, the torque increases as the swab reamer traverses through the curve (shown as points 2 to 3 in Figure 4). The torque then levels off and becomes consistently lower as the reamer traverses through the bottom tangent, represented as the line from points 3 to 4 in Figure 4. An increase in torque is then seen as the swab traverses through the final curve, from points 4 to 5 in Figure 4, and finally decreases throughout the exit tangent section of the reaming pass.

Figure 5 shows the torque as a function of length during the first swab pass and the torque that was recorded during the reaming pass. There are three significant things to note from Figure 5. First, the torque significantly decreased at the location where the reamer became stuck, signifying that the pull-back and re-reaming of that section of the bore was successful at clearing any blockage. Second, the torque that was realized during the swab pass in the first curve, between points 2 and 3, was similar in magnitude to when the bore was reamed with the 24-inch. This should not be the case as the barrel swab was smaller than the borehole and indicates that there is a possible bore collapse in the first curve. Third, the torque during the second curve was comparable to the torque realized during the 24-inch reaming pass. This indicates that the borehole may have collapsed and was not properly prepared for the pull-back.

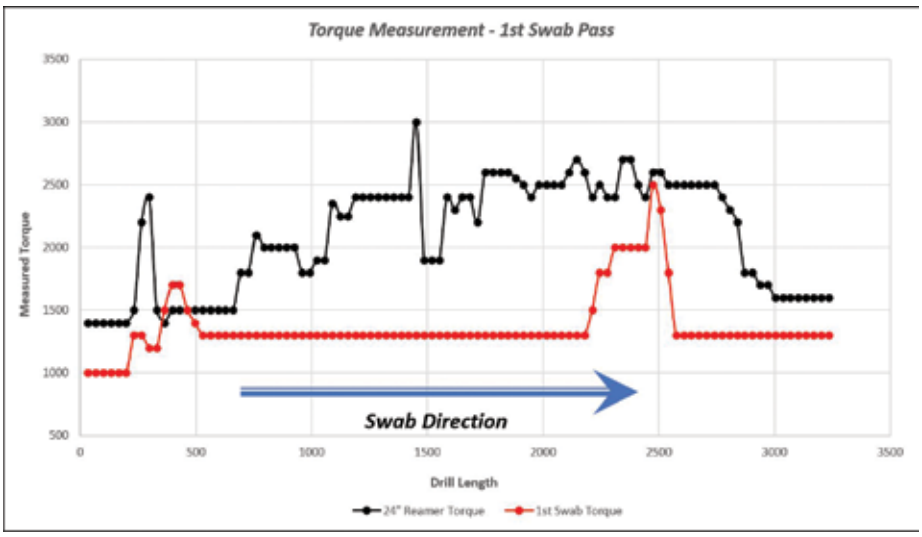


Figure 5. Torque during 24-inch reaming pass and initial swab pass

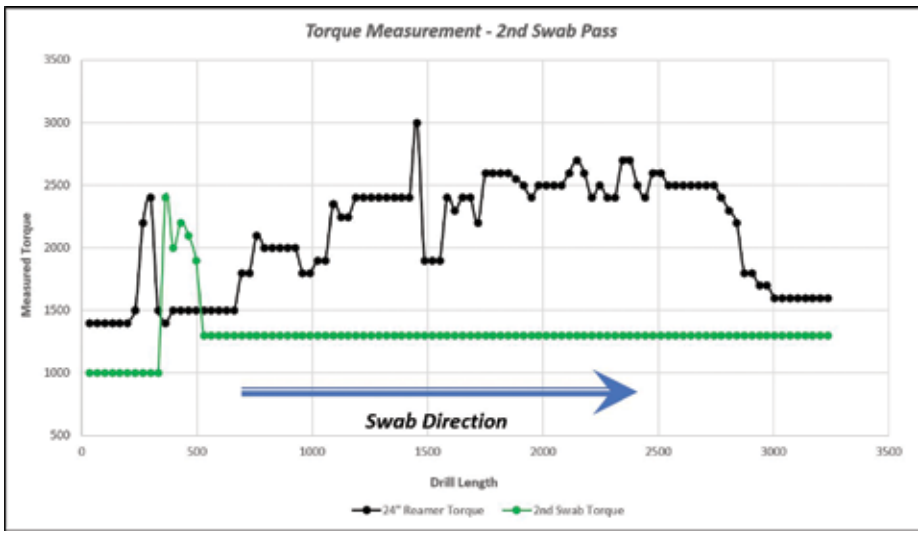


Figure 6. Torque readings during 24-inch reaming pass and 2nd swab pass

These results were graphed real-time in the field and discussed with the contractor and Owner. Alarmed by the torque recorded during the initial swab pass, the contractor elected to re-swab the bore while evaluating the torque to determine if the initial swab pass resulted in further cleaning of the borehole.

Figure 6 shows the torque during the 24-inch ream and the second swab pass. The second swab pass indicated that once again the bore had collapsed in the first curve during the swab, but the increase in torque was seen later in the curve than had occurred in the first swab pass by approximately 50 feet. During the second swab pass, the second curve did not show indications of collapse, indicating that the first swab was able to clear the soil from the borehole. The rotary torque during the remainder of the borehole remained stable.

Since the borehole had been swabbed twice and the majority of the bore showed low torque, indicating a stable borehole, the contractor elected to pull the product pipe into the bore after the second swab pass. Pull forces throughout the first curve showed increased loading, however, since this was a short section of the overall bore length and occurred at the beginning of the bore, the pipe was pulled into the borehole without incident.

RMI AND MID-SIZED HDD

While the example above describes a maxi-sized HDD installation of over 3,000 LF, the same principals of risk identification and management have been very effectively applied to mid-sized HDD installations in the 4 to 12-inch diameter and 400 to 1,000 LF lengths. It is important for the inspection program to be tailored to the installation type. The data being tracked and recorded for a maxi-HDD may not be practical for mid-sized HDD. Inspectors must realize the purpose behind the data collection based upon the risks that are being tracked and coordinated with the Owner. Risk items such as over-stress in bending, field changes to alignments to minimize disturbance while still meeting the specifications, and potential challenges during the pull are all potential construction occurrences that can be effectively solved with an active risk management and tracking approach.

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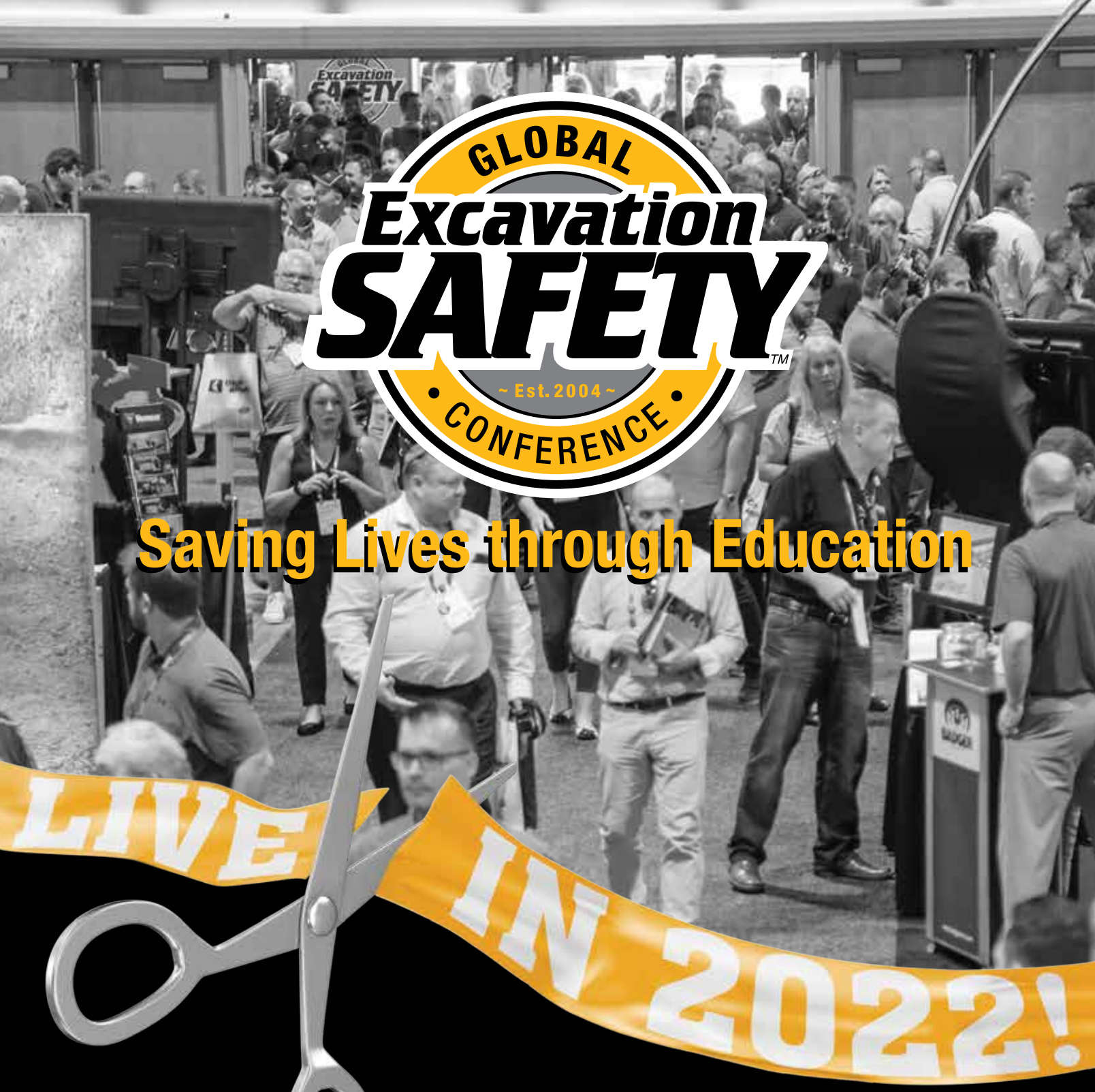
ABOUT THE AUTHOR:

***Kimberlie Staheli, Ph.D, P.E.**, is the President of Staheli Trenchless Consultants. As a researcher with the USACE, Dr. Staheli was the author of some of the first research studies on HDD and trenchless construction mechanisms in the United States. She is passionate about using her 30 years of field and design experience to mitigate trenchless risk.*



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The Future Is Bright for Vacuum Excavators

Pandemics and climate change have a positive impact on the vacuum excavating industry

By: John Walko, Excavac

Third in a series of articles on Vacuum Excavation Technology

Vacuum excavating has continued to march in step with trenchless technology for the last three decades, at least in the United States. While still relatively under-appreciated beyond the gas utility/horizontal drilling environment, with an exception being the utility locate industry, I maintain that applications for this arthroscopic excavating technology continue to develop. We have seen that the buried utility infrastructure in the US has functioned throughout the Covid-19 pandemic with hardly missing a beat. It has been a testimonial to their ability to provide dependable energy throughout the pandemic. We do also note that the weather related electric power issues in Texas this past winter were rooted in surface or aerial systems, not buried cable or pipeline problems. Lessons learned here were many, with particular note to the vulnerability of exposed lines. This lesson will reinforce the secure aspect of burying more and more of our utility distribution lines. The more utilities are put in the ground, the greater the demand for vacuum excavators.

As markets develop, the established ones continue to expand as well. One example is the utility locate industry. A big driver in that market is the demand for more and more data points to accurately pinpoint buried lines. This is being pushed by many of the large engineering companies, and even the utilities themselves. Any pothole locate that actually exposes a buried line, presents an opportunity for another accurate GIS/GPS data point. There is a need for countless more of these data points before computers are able to extrapolate the location of buried lines accurately. Utilities are becoming aware that any type of excavation on their lines presents an opportunity for data points. While locators are primarily set up for this, it becomes a natural extension for the existing vacuum excavator crew. It would be easy to add another line on their current job reporting form.

Although vacuum excavation became truly established as a viable technology in the gas industry, there is still a lot of room for growth here. The technology still seems to be concentrated in certain parts of the country. It has been readily accepted in Florida, where the sandy soil has some of the best digging conditions in the country. The rocky Northeast has become a good area, mostly due to restoration savings, in spite of a much harsher digging environment. The East Coast remains busy, in large part because of damage prevention concerns pushed in the State of Virginia having a positive effect on neighboring states. The damage prevention aspect of vacuum work is becoming a driving force in other parts of the country as well. I see it happening more in the Midwest, although the Chicago region was an early adopter of vac excavation. While being noticed for other things these days, Maricopa County, AZ was another area that quickly adapted to the new technology. It remains a leader in safe digging and damage prevention. The hard caliche soils in Texas and New Mexico lend themselves to the bigger hydro-vacuum trucks, which are still safer than backhoes and track excavators. The effectiveness of the technology while performing a safe excavation is finally being noticed around other parts of the country. While demand will naturally be higher in urban and suburban settings, interest is now being generated in more rural areas of the country. I feel this is due to a greater acceptance of the technology, albeit 50 to 60 years after early use.

While most vacuum work is bid out to independent contractors, occasionally the work is brought in-house at the utility. In this instance, the communication link between the technicians and management is extremely critical. While inherently safe, it is still rough physical work, with the more experienced technicians working with the equipment, not fighting it. Therefore, the communication lines need to be such that everyone knows what to expect on any given procedure. If that goes out of whack, frustration quickly builds on both ends. This in turn leads to a rapid drop in productivity, and a major under-utilization of the equipment. A successful in-house vacuum program is something to behold, while no one can get far enough away from a bad one. With an independent contractor, the dynamic is totally different. It is much easier to incentivize a good team of technicians, and production goes up accordingly. Thus, creating an effective, efficient in-house program is challenging for sure, but it can be very rewarding for the utility, both in cost savings and worker/management relations.

Primary uses in the gas industry continue to be the setting of sacrificial anodes, attaching test lines, service cut-offs (kills), and even pothole locates. The latter

A major growth opportunity for vacuum excavation is in the electric utility market

> *"Applications for this arthroscopic excavating technology continue to develop."*

is especially true on common trench situations with other critical utilities. All of these applications are still in a growth phase that will continue for years to come. Meanwhile, much hasn't changed in the basic design of the vacuum systems, with some attention being given to filters more than anything. You will see some new bells and whistles occasionally, but the work is still physical by design. Improvements to the extension tools that help generate the hole to the affected line, or the tools that perform a specific job on the line are happening all the time. This continuously helps push the technology further along.

Although this article is written for a magazine dedicated to gas infrastructure, a major growth opportunity for vacuum excavation is in the electric utility market. To be more particular, for the buried residential distribution side of the electric market. More and more electric cables are being put in the ground, as they remain relatively safe from extreme weather conditions. High winds, ice storms, falling trees, vehicle accidents, all have a negative impact on aerial lines. This is all negated by burying the lines. Progressive developers and municipalities have been doing this for years, and it only makes sense that this will continue. Some utilities have already instituted programs to put more of their existing aerial lines in the ground. While this minimizes weather issues, there are still other conditions that can create a break or fault in the buried line. This is happening more frequently with older buried lines that are subject to insulation breakdowns leading to a corrosion induced fault. These faults are now often handled by a crew with a backhoe digging a hole big enough for a worker to access the problem fault. This is where the gas industry was 30 odd years ago. Back then a gas crew with a backhoe and dump truck would dig a hole big enough for a person to work in. The work was often in a street or driveway, and they would do a procedure in the morning, and another in the afternoon. If all went well, they would do two procedures on a good day. The advent of the arthroscopic vacuum excavation made the whole procedure not only safer, but far more productive, and way more efficient, especially with restoration times and materials. I can see the same forces at work in the electric industry. This will become a major boon to vacuum excavation.

The technology continues to get noticed by other markets. These range from landscapers to plumbers to farmers. Literally anywhere someone could use a 30 Hp vacuum system, with a water-jet or air compressor thrown in for good measure. The vacuum system can be readily scaled up as required for a particular application. With established markets still expanding, and new ones coming along, especially servicing buried electric distribution faults, the future for vacuum excavation is very, very bright.

Older buried electrical lines are subject to insulation breakdowns

ABOUT THE AUTHOR:

John Walko is a designer of industrial and commercial vacuum systems since 1973. Founder and President of Excavac Corp since 1989. Charter member and Lifetime Board Member of NULCA (National Utility Locate Contractors Association) 1993-present. Served on Steering Committee of Common Ground Study 1998-99. Participant on Common Ground Alliance Transition Team 1999-2000. Remains active with the Common Ground Alliance.

Nondestructive Onsite Grade Verification for Trenchless Applications

By: Mona Haggag, ABI Integrity Services

Trenchless methodologies represent an innovative and critical approach for the safe and effective management of pipeline infrastructure. The uptake has required collaboration between research firms, contractors and pipeline operators working together to advance a multitude of technologies.

In the material verification space, with the Pipeline and Hazardous Materials Safety Administration (PHMSA) Mega Rule taking effect in 2021, there has been tremendous pressure to develop industry solutions to nondestructively assess pipe grade and safe operating pressure. In-line inspection tools have proven invaluable for corrosion assessment, and currently, there are a handful of available methods to assess material strength and toughness. This is not a new need, and indeed, in the nineties when the first Stress-Strain Microprobe® system was developed and patented, there was pushback from conventional destructive testing providers. However, despite pushback on ASTM standardization committees during that era, the technology was still used by top US national laboratories and verified for use by their internal teams. In 1996, the technology received the R&D 100 Award under the name *PortaFlow-P1 Portable/In-Situ Stress Strain Microprobe System®*. Fahmy Haggag, the inventor, accepted the award on behalf of his firm, Advanced Technology Corporation.

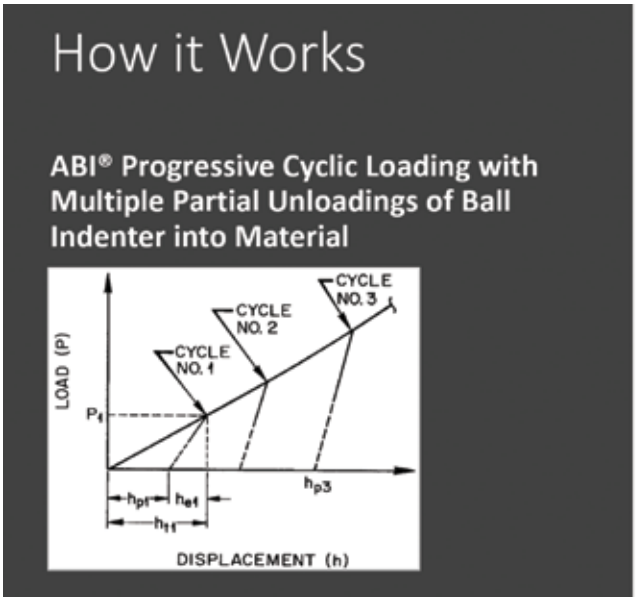
Fast forward to the present, the technology is now commonly known by its non-destructive test technique as Automated Ball Indentation® (ABI®) and has been used by nuclear facilities, pipeline operators, water companies, and aerospace firms to nondestructively verify their assets.

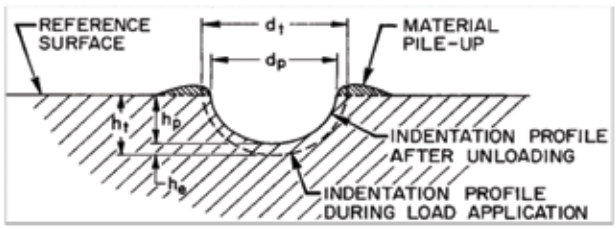
WHAT IS ABI®?

ABI® is a nondestructive mechanical testing technique for determining Tensile and Fracture Toughness Properties. It is based on progressive indentation with intermediate partial unloadings until the maximum depth (maximum strain) is reached, and then the indenter is fully unloaded. The ABI® test is a macroscopic (bulk) technique that measures the properties on a small volume of metallic materials.

PORTABILITY AND SPEED

During an excavation, particularly in high density areas, speed to test and concurrently assess pipe grade can prove critical to cost control, savings, traffic control on paved streets and site management. While the ABI® method was initially developed and used for nondestructive structural integrity assessment of nuclear





Calculation of Stress-Strain Curves

	Tensile Test	ABI® Test
Data Parameters	(1) Tensile Load, (2) Sample Extension	(1) Compressive Load, (2) Progressive Indentation Depth
Stress	Load / Cross-Sectional Area	Load/ Effective Indentation Size
Strain	$\Delta L / L_o$	Constant x (Indentation diameter / Indenter diameter)

Figure 1. ABI Testing is based on progressive indentation with intermediate partial unloadings until maximum strain is reached

Figure 2. Requiring minimal space, the system is lowered into keyhole and removed in less than an hour

pressure vessels; the applications have grown across the last three decades. More recently, applications for pipeline operators have proven beneficial for grade determinations and material verification, but also for meeting tight excavation and construction schedules.

Both the ABI® test method and overall speed of the technology allows operators to realize significant savings and safety advantages over conventional destructive testing costs. Our technicians are trained and certified to provide testing services on in-service pipelines and pressure vessels.

ABI® provides a nondestructive measurement of tensile properties and fracture toughness that eliminates the need to cut any samples. In fact, our ball indentations are shallow, with smooth edges and produce compressive stresses in the material that retard crack initiation.

The indentation is shown to scale on a dime. Each test is performed in under five minutes (three tests per location are recommended to determine average values and their standard deviations) and measure the following key mechanical properties:

- Yield Strength
- True-Stress/True-Plastic Strain Curve
- Strain-Hardening Exponent (n)
- Strength Coefficient (k)
- Uniform Ductility
- Ultimate Strength
- Initiation Fracture Toughness

ABI® is an ideal technique for measuring material properties – tensile and fracture toughness - quickly and nondestructively. The testing system can be lowered into and pulled out of the keyhole in less than an hour and immediately provide the data and results needed.

Figure 3. Indentation shown to scale on a dime. Each test is performed in under five minutes

ADDITIONAL VALIDATION

In 2007, Shell Pipeline Company sponsored a Pipeline Research Council International (PRCI) report that complemented their internal validation efforts. BP supplied data on tank steel that was also tested for before the publication. This 94-page report, titled "L52280 In-Situ Measurement of Pipeline Mechanical Properties Using Stress-Strain Microprobe – Validation" is available through www.prci.org. In the report, materials are tested at varying temperatures with consistent data integrity – "an appropriate and relevant amount of data from the nondestructive Automated Ball Indentation® (ABI®) tests and the destructive tensile and fracture toughness tests provides reasonable statistical data sets to establish the validity and accuracy of the ABI technique which produces both tensile and fracture toughness properties from each single test." The ABI® Standard Test Method and its precision values from a 6-lab Round Robin (ILS) study is included on pages 36-60 of the report.

When applied to in-service pipelines, the test can provide considerable savings because operators are able to quickly close the excavation. And when timing is coordinated across contractors, some operators have been able to open, test, and close up to 12 locations in one day using only one testing team.

SYSTEM PLACEMENT WITHIN KEYHOLE

There is a minimal amount of space required to conduct a test – a 14x4-inch surface area is needed for the magnets to affix

to the outer pipe surface. The coating must be removed for the magnets to properly operate, but only a 1 x1-inch surface area requires a white finish polish to conduct the test (using a 220 grit polishing disk). The surface does not need to be flat, only smooth. The resulting ball indentation does not need to be buffed out afterwards because it creates a spherical indentation that is akin to shot-peening (an application commonly used in the aerospace industry and plane fuselage to prevent fatigue cracks). The system is attached/connected to the electronics/control cabinet via protected cables that can extend up to 30 feet so key-hole depth is not an issue when testing.

DETERMINING MAXIMUM ALLOWABLE OPERATING PRESSURE (MAOP) WITH VARYING WALL THICKNESS

Smart-pig MFL tools and nondestructive ABI® testing are complementary. A salient example is a run that discovered a 50-foot pipe joint (12-inch outer diameter) with a reported wall thickness of 0.281 inches while the rest of the pipeline had a wall thickness of 0.312 inches of Grade X52. It was obvious that the uniformly reduced thickness was not due to corrosion but, most likely, because the original joint was replaced due to severe localized corrosion (the pipe joint was in a swamp area).

The ABI® tests determined and confirmed that the joint met Grade X65 for the mechanical properties' requirements so the maximum allowable operating pressure (MAOP) of the line did not need to be lowered since the increased Grade of X65 (instead of X52) compensated for the reduced thickness. The MAOP is a function of three parameters (specified minimum yield strength "SMYS" x wall thickness / pipe outer diameter), in addition to the various mandatory factors of safety.

PREVENTING A TANK FRACTURE WHEN INSERTING A NEW NOZZLE

Another application for ABI® has been to determine the fracture toughness of a storage tank wall before cutting a plug for a new nozzle/outlet fabrication to ensure no brittle fracture could occur during the modification. ABI® testing has been able to measure tank wall mechanical properties to achieve modifications safely. The software calculation provides instant information, so it is particularly useful when trying to avoid additional asset damage.

DOES INTERNAL PRESSURE OF AN IN-SERVICE PIPELINE AFFECT THE ABI® TEST RESULTS?

A common question is whether internal pressure of an internal pipe can impact the test. The good news is that internal pressure or hoop stress condition creates only elastic stress on the internal surface of an in-service pipeline. The maximum allowed hoop stress cannot produce yield strength of the pipe in order to avoid pipeline bulging and any potential failure. Hence, the elastic stress (which is lower than the yield strength by the margin of safety used in the MAOP) cannot affect the test results of the ABI® test.

CONCLUSION

As we move out of this pandemic era into increased focus on compliance and achieving safe, cost-effective solutions, technology adoption will be critical for our industry. As operators assemble their plans for the coming decade, we look forward to continuing partnerships with both operators and contractors in advancing cost-effective and technically sound and accurate solutions. While the technology described has been used and validated numerous times over the years across multiple industries and used in over twenty countries, there is still expanding opportunity for continuing to provide value as the PHMSA Mega Rule takes effect.

ABOUT THE AUTHOR:

Mona Haggag *is the President and CEO of ABI Integrity Services, a certified WBE & WOSB. She is also a principal at Continuum Advisory Group, a consulting firm providing solutions to the engineering and construction industry. Her clients have included pipeline operators, mechanical contractors, building trade unions, industry associations, and the Federal Government. Her expertise is in change management and modernizing industry through research, technology transfer, and technology adoption.*

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The Opportunity for Remote Inspection to Address Talent Gaps:

Leveraging Technology Advancements in Remote Inspection to Improve Culture and Tackle Talent Shortages

By: Dan Lorenz, P.E., Joe Knows Energy

CHALLENGES IN CULTURE AND TALENT

It has become increasingly complex to manage pipeline, gas, and utility projects. Enhanced regulation and new documentation needs keep leadership teams on their toes – struggling to keep their construction personnel and inspection teams compliant with reporting, safety, and environmental needs.

Complexities get worse when we factor in the issue of our most experienced professionals retiring out of the market. We have to train and develop new hires with little field expertise in an increasingly complicated environment. The situation does not have to be bleak. There is a substantial opportunity to leverage advances in technology to improve employee training, managing quality and safety, and enhancing overall performance.

THE UTILITY INDUSTRY IS OPEN TO CHANGE

In winter of 2021, an AGA Operations subcommittee conducted a presentation about remote inspection. During this event, the audience was polled about remote inspection. Respondents were asked if they current had a remote inspection program and 45% expressed some interest in a remote inspection program. The adoption was **still very early and vague with 31% in the process of defining a pilot and discussing scope. Only 3% of respondents actively have a program while another 10% were actively engaged in a pilot**.

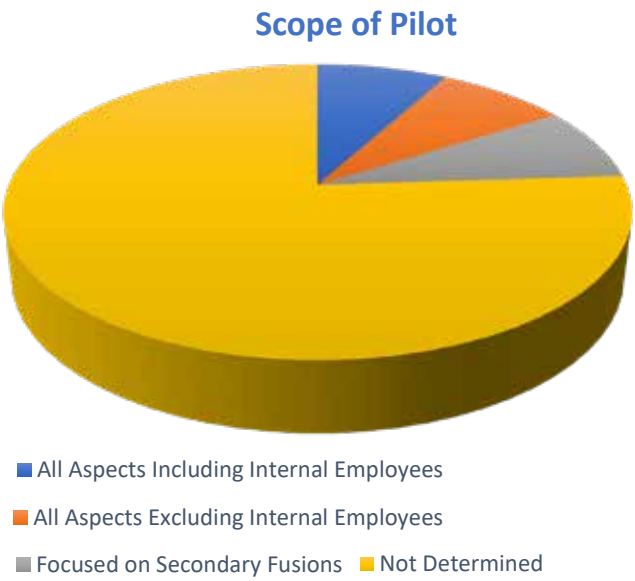
For those who were interested in pilots, 75% had still not determined the scope of their pilot. Among the rest, respondents were evenly split between pilots aimed at all aspects of their program including internal employees (8%), all aspects of their program excluding internal employees (8%), and pilots exclusively focused on secondary fusions (8%).

Are We Ready for Remote Inspection?

I took notice of the idea that, although remote inspection was the most desired topic for this subcommittee, **the industry has not aggressively explored utilizing remote inspection**. Further discussions confirmed my assumptions. Most of the delay in the industry with adoption comes from lack of clarity, concern about investment, and uncertainty in relation to new rules (e.g., Mega Rule).

How to Utilize Remote Inspection

Many companies see fusion inspection as a good target for remote



inspection with its' many critical events and higher cost of live inspections. Other companies are exploring contractor self-reporting as an application for remote inspection. These companies have expressed concerns, however, that the next phase of the Mega Rule may not allow self-reporting. Many are waiting for more clarity and delaying efforts to ensure they can roll the cost of inspection into the construction cost.

Concerns about Remote Inspection

Still, many business leaders' concerns are focused on material tracking, traceability, and digital as-built in requirements. They want to develop a comprehensive solution and are hesitant to add to their third-party inspection. If they do utilize an inspector, they are hoping for less expensive (less experienced) inspectors.

Is the Technology Consistent Enough?

Those who have done testing and experimentation with remote inspection have other concerns. Business leaders have expressed concerns about video quality, WiFi connection, clarity of video to see specific areas, and storage of the volume of video required. As technology improves and advancements are made, better technology becomes less expensive. This will help aid concerned business leaders to ensure they have the technology needed at a reasonable cost to deploy their programs.

PILOT PROGRAM

Having built strategic partner relationships with our utility clients, Joe Knows Energy has the unique opportunity to pilot remote inspection programs with our clients. We've recently begun a pilot program with one of our clients utilizing RealWear's Hands-Free Wearable Tablet Computers to test the results related to productivity, training, and documentation.

> *"The industry has not aggressively explored utilizing remote inspection"*

Our hypothesis is that the remote inspection program will allow support staff to visibly view and assess issues with less downtime and reduced travel costs; improve training with remote mentors who can collaborate hands-free and support frontline inspectors; and streamline documentation processes to improve documentation for various project needs.

Productivity

Typically, engineers, managers, and senior inspectors are required to visit jobsites when technical issues arise. This occurs approximately twenty times a year per crew on complex projects. During our pilot, an engineer was able to utilize the headset to identify an issue before it became a problem for the crew. The engineer held a Microsoft Teams meeting to discuss and address the issue and a 2-hour trip to the jobsite was handled in twenty minutes. Crews were able to get to work immediately. The hands-free feature is a powerful tool to improve productivity, allowing the inspector to

point out parts of the jobsite without having to carry about a tablet or computer.

Training

With a large number of experienced inspectors retiring, much of the historical institutional knowledge is leaving organizations. The need for more inspector presence coupled with this loss of talent makes coaching and mentoring opportunities on-the-job even more

attractive. Equipped with a high-definition camera, powerful audio, and unmatched noise cancellation capabilities, hands-free remote inspection devices enable field inspectors to get assistance from the most experienced inspectors and subject matter experts over a two-way video call. This allows organizations to hire less experienced inspectors, offer real-time training, and elevate the culture while dealing with constraints of available talent and budget.

Documentation

Maintaining documentation is a challenge every project leader is familiar with in this industry. Increased or changing documentation increases the time and skill required to be compliant. This can be a drain on the time of your most experienced technical experts resulting in increased costs of inspectors. Combining remote inspection with a more thorough, detailed inspection report gives project leaders the opportunity to spot trends to guide improvement efforts. Inspection forms can be completed with voice commands that allow inspectors to take pictures, make notes, and document activity with a few words. Over time, deeper integrations with other tools and software solutions will create complete tracking, asset recording, and traceability.

REMOTE INSPECTOR PROGRAMS

As a result of our remote inspection pilot program, we will be able to educate our clients' engineering, management, and construction teams on how to effectively deploy remote inspection programs. This will help our clients achieve the improved performance that comes with a well-executed program including improved decision making, increased capacity, streamlined documentation, decreased cost, and proactive handling of potential issues or downtime.

In an environment where a culture of transparency and accountable is desired to reduce incidence and safety issues, we face challenges optimizing our internal processes and handling unforeseen conditions and variables outside of our control. When we achieve an acceptance of technology, virtual meetings, rapid response time, and better training, it is our position that there could be a 10X return on investment when total costs are considered.

FURTHER INFORMATION

For more information on how we at Joe Knows Energy are progressing with remote inspection, please consider joining us as we dive deeper at the AGA Conference in Orlando on October 5th-8th! We will also be featuring a remote inspection demo which will highlight the Realwear headsets at our company booth during the conference.

ABOUT THE AUTHOR:

Dan Lorenz P.E. *founder and president of Joe Knows Energy, has over 30 years leading construction, training and inspection services companies. He is passionate about elevating safety and quality cultures with frontline professionals. Joe Knows Energy provides staffing, recruiting, and consulting services to the utility and energy industries. To find out more, visit their website: www.joeknowsenergy.com or contact Dan at 614-989-2228 or dan@joeknowsenergy.com.*

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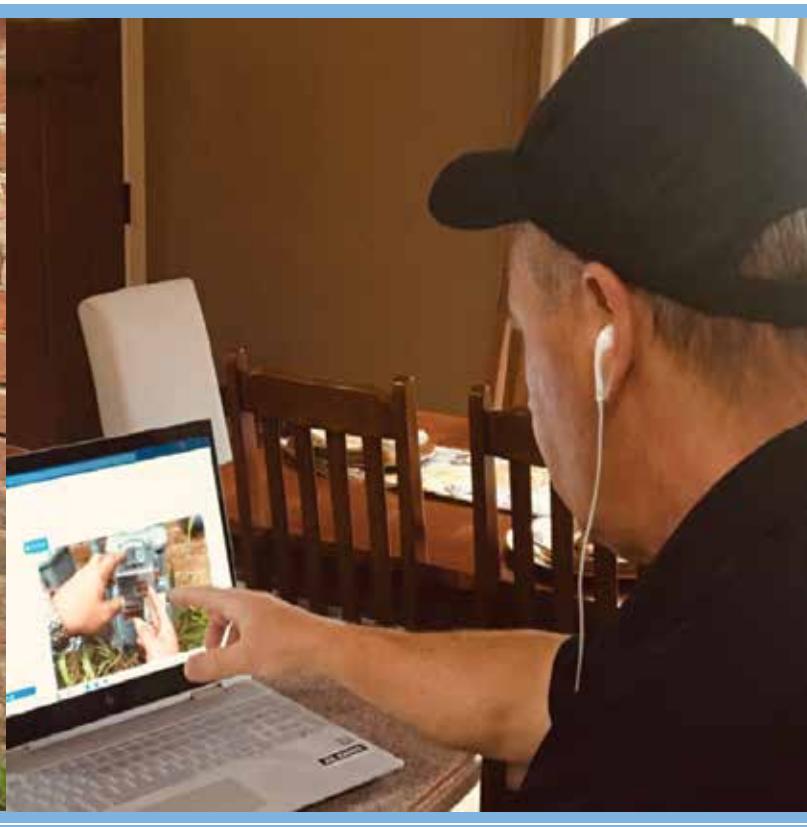

CONSIDERING REMOTE INSPECTION?

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Our Remote Joe program is a great opportunity to pilot remote inspection in your organization. At Joe Knows Energy, our team is running remote inspection pilots with organizations like yours to combine the seasoned experience of chief inspectors, engineers, coordinators, supervisors, and subject matter experts with technology to coach and guide inspectors in the field.

OUR EXPERT TEAM IS HERE TO HELP EVERY STEP OF THE WAY

IDENTIFY PROJECT NEEDS AND DEFINE PILOT SCOPE	STAFF COORDINATOR, SUPERVISOR, AND INSPECTORS	LAUNCH PILOT PROGRAM AND MONITOR RESULTS

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Fixing Leaks with Encapsulation

By: Miller Pipeline

Fixing leaks with encapsulation is a passion of Teddy Vance. Vance is a foreman with Miller Pipeline, a natural gas distribution and water/wastewater pipeline contractor operating in over 20 states. In the 12 years he's worked in natural gas, Vance has been focused primarily on encapsulation jobs in major metropolitan areas in the Mid-Atlantic region of the United States.

Vance's crew has been anything but slow over the past 18 months. "We have six projects in various stages of planning right now. Yesterday we encapsulated a 24-inch main tapping sleeve with a 12-inch valve," he said. His crew is dedicated solely to sealing leaks on aging steel and cast iron natural gas systems that, in some cases, are over 100 years old.

A custom-made mold is lowered into the excavation before being installed onto the leaking fitting

"The Mid-Atlantic region has so much steel and cast iron, and it's slowly being replaced with plastic, but some of the mains go from three inches up to 48 inches in diameter," Vance said. "These larger mains are more difficult to replace."

As experienced by so many companies, repairing a leak can be more cost-effective and practical than cutting out the fitting or replacing an entire section of pipe. And in major, congested cities, shutting down traffic for a complete open cut replacement may not be an option.

Another challenge, Vance said, is that while utilities are working to replace steel or cast iron with plastic, they frequently have to leave the old steel or cast iron lines in the ground because of congestion underground. "Digging in this area is difficult, as there are so many utilities in the ground which sometimes makes it really complicated to get holes big enough to install steel mold encapsulation," he said. "But with cast iron, there's a joint every 12 feet (typically), which means there's a potential for up over 400 leaks for any given mile."

To ensure no interruption of service, all of Miller Pipeline's encapsulation jobs are performed on live gas mains at normal operating pressure. On a typical job, the pipe will cleaned by descaling and sandblasting, then a proprietary primer is applied. The primer displaces moisture and creates a good bond surface for the encapsulation to adhere to the pipe. Once the primer dries, the next step is to install the steel mold. "We install the mold and fill it with encapsulation, then pressurize with nitrogen to overcome main pressure, sealing the leak," Vance said. "We allow it to cure for a minimum of 12 hours, and

A steel mold, custom made at the Miller Pipeline fabrication shop in Indianapolis, after the leak has been repaired

The crew preps the Encapseal resin for pouring

After descaling and sandblasting, the fitting is ready for primer

then remove the mold the following day.

"When fully cured, Encapseal provides a flexible repair," he said.

Vance added the propriety steel molds are an integral part of the Encapseal product and process. Molds are manufactured in Miller's Indianapolis fabrication shop. Occasionally the molds are able to be reused on similar fittings, reducing wait times for future projects and reducing costs for customers. Once the mold arrives on the job site, it typically takes two to three days to complete the encapsulation.

On a recent large job, Vance's crew encapsulated a 20-inch valve tapping sleeve on a 20-inch cast iron main supplying gas to hundreds of homes and an entire college campus. That job required 608 liters of Encapseal to be poured. Once it was completed, they were proud of the final product and had a great sense of satisfaction that they had kept gas flowing without disturbing residents.

ABOUT MILLER PIPELINE:

MILLER PIPELINE

AN ARTERA COMPANY

A leader in building and maintaining America's infrastructure for over sixty-five years, Miller Pipeline is one of the nation's premier natural gas distribution, transmission pipeline and utility contractors.

To find out more about Encapseal, visit www.millerpipeline.com/encapseal/

Problem Sealed!

When it comes to leaks, Miller Pipeline has the problem sealed with ENCAPSEAL® Safe-T-Seal®. Miller brings leak repair technology to a new level of reliability, safety, ease of installation, and cost-effectiveness through our external encapsulant sealing system. ENCAPSEAL® Safe-T-Seal® is designed to externally repair and seal leaking joints on steel and cast iron. ENCAPSEAL® is the brand of our encapsulation products, and Safe-T-Seal® is the two-part polyurethane resin that forms the repair seal. This American-made polyurethane resin formula has been made for Miller Pipeline for over 30 years.

There are many concerns surrounding sealing pipes in the gas industry. ENCAPSEAL® Safe-T-Seal® remedies many of those concerns. The two-part polyurethane resin is formulated to be below any NIOSH/OSHA established hazardous levels of carcinogens, contains no coal tar, methyl ethyl ketone and when used as directed, no fresh air breathing equipment is required under NIOSH/OSHA, providing a safer environment for installers. The safety of our employees, installers, and communities we work in is our number one priority.

Miller Pipeline has designed many ENCAPSEAL® kits to fit various industry standard pipe sized fittings. Safe-T-Seal®, we provide a kit with all the materials you need to get the job done. For a standard low-pressure bell joint kit (less than one psi), we provide the two-part polyurethane resin formula, a primer, the cloth fitting, installation bands, additional assembly parts, and instructions. Our medium pressure kits provide similar items and designed for mains pressures up to 30 psi, but this varies depending on the size of the main. We also provide custom designed molds to fit bell joints, mechanical joints, valves, tees, sleeves, and more. The ENCAPSEAL® Safe-T-Seal® is rated up to 60 psi.

Part of the Indianapolis-based Encapseal® manufacturing team

Example of ENCAPSEAL® kit

The ENCAPSEAL® Safe-T-Seal® kit includes an instructions guide to assist you through the process. You start by grit blasting the area the repair seal is to be installed, then brushing the primer on the area just grit blasted. Once it is primed, the repair kit is installed and the two-part polyurethane resin formula is mixed and poured into the cloth fitting. Gel time of Safe-T-Seal is approximately 15-20 minutes, depending on the outdoor ambient temperature. Although Safe-T-Seal® maximum strength is achieved in five to seven days, depending on the type of repair being made, the excavation can be backfilled in about an hour after being sealed.

"We feel that our expertise in this field has put Miller Pipeline at the top of the encapsulation process," said Larry Shaw, Manufacturing Manager at Miller Pipeline. "Miller Pipeline has been repairing leaking joints and fittings for at least 40-years. We are also the only joint seal repair contractor to make steel molds in our fabrication department for this type of repair."

With better performance than its peers, ENCAPSEAL® Safe-T-Seal® is simply better for our customers. We provide a one-of-a-kind product backed by years of performance.

Pipe Slitting Slashes NG Line Replacement Costs

Gas providers reporting 40 percent reduction in unit cost vs open cut, 25 percent vs HDD

By: HammerHead Trenchless

The pipe slitting method used in gas line replacement has been steadily gaining popularity the past 5- 10 years. Mike Walk said it reflects the success of new, winch and customized tool designs. Bad experiences with the method prior to these tooling advancements may have caused some heartburn within the industry using the method. Operations are reporting that the method is not only reliable but reduces cost per unit as much as 40 percent over open-cut methods and up to 25 percent over horizontal directional drilling (HDD).

Walk has been involved in the evolution of these tools since mid-2000s as a field technician, application specialist and product manager for HammerHead® Trenchless, a Charles Machine Works company based in Lake Mills, Wisconsin. During that first decade he knew of only two or three companies who had adopted the trenchless slitting method as an essential part of their distribution maintenance strategy out west. Today it is being specified by providers on the East Coast, in the Deep South and in eastern Canada. Some of the companies are using it to replace up to 1,000 feet of pipe in a day in large-scale, legacy pipe replacement initiatives.

"We've seen it take off wherever gas providers have undertaken large-scale pipe-replacement programs," Walk said. "And we're on the verge of seeing it grow exponentially as gas providers in the Midwest and south-central region start replacing pipe with their own initiatives. That's coming soon."

The surge of confidence in the pipe slitting method is due to the effectiveness and reliability of the new tools, Walk said. HammerHead has added its patented, application-specific, pipe-splitting tools to its Same Path™ technology line. Tooling setups are available for plastic pipe materials including Adyl-A, PVC, HDPE and MDPE, as well as for cast iron and steel. Specialized tooling for copper and steel pipe extraction is currently being field-tested throughout Canada.

Hydraulic rod-pulling machines are typically used for steel pipe and larger plastic pipe slitting operations. This rod-pulling machine is being set up for a 460-foot-long, size-on-size replacement of 4-inch steel gas line with 4-inch MDPE.

Cable winch being used to slit 4-inch plastic pipe. Pulling force for the operation is kept in-line with the bore axis by means of a self-deploying boom, which needs only a small pit to work from.

Modern pipe-slitting tools are purpose-built to form configurable, flexible tool strings that navigate the irregular path of plastic pipe. The slitting head slits the existing pipe into multiple, uniform strips, creating a smooth, new bore for new pipe drawn in behind it.

PURPOSE-BUILT TOOLS

The evolution of advanced pipe-slitting tool design is rooted in the Southwest United States, Walk said. It began when natural gas providers there were looking for a safe, more cost-efficient way to replace legacy plastic gas line pipe in their distribution systems. A trenchless method known in the industry at that time as "pipe-splitting" held great promise. In principle, new product pipe attached to a splitting head can be simultaneously drawn inside an existing gas pipe by a hydraulic pulling machine as the head splits the existing pipe apart.

The method offered potential advantages over open-cut replacement and as an alternative to HDD technique. As a trenchless application, the pipe splitting method eliminates the time and expense of full-length excavation and restoration. Compared to using HDD for drilling in a new line, the pipe splitting method offers a much smaller footprint, utilizing smaller machines. And because a pipe splitting operation follows the exact same path of the existing pipe, it can often be used in conditions that prohibit the use of HDD.

Early on some contractors had attempted to use sewer-pipe bursting systems, utilizing a pneumatic hammer and winch. These tools were not ideal for use on plastic pipe, as the tool could not navigate the bends in a plastic pipe path. The method often caused plastic pipe to jam or buckle, overheat and melt due to excessive friction of new pipe against existing pipe. Tooling that jammed up midway through a run required excavation, defeating the purpose of a trenchless method and greatly compounding project costs.

In search of tooling designed to meet the unique requirements of plastic gas line replacement, the providers worked closely with Ditch Witch of California, who teamed up with HammerHead, a manufacturer that since its inception has dedicated itself to providing tools, equipment, consumables and education for trenchless pipe installation, rehabilitation, replacement and repair.

PLASTIC PIPE REQUIREMENTS

Walk said that while cast iron, steel and large diameter plastic pipes lie flat and straight in the pipe bed, plastic pipe sways and bends. The new design of modern plastic pipe tooling is based on a flexible, configurable tool string of more appropriately sized components. The string negotiates the irregularities in a plastic pipe path without excessive friction, while consistently slitting the existing pipe into multiple, uninterrupted strips throughout the full length of the run. The increased effectiveness of the tool string gave rise to this method's other term, "pipe slitting."

The tool string also features an integrated breakaway to prevent stressing the new HDPE pipe midway through a run. The breakaway ensures the new pipe and tool string stop prior to encountering the stress on new pipe if the tool string encounters a change in direction too great to overcome.

The improved design of modern tooling also permits easy, individual replacement of components such as blades, expanders and breakaways, extending the tooling's useful life expectancy.

Although plastic pipe was the focus of design in the beginning, it became apparent that designs of slitting tools available for steel gas pipe were also less than ideal. The standard tools in use for steel pipe splitting were basically modifications of earlier designs used to fracture cast iron. Unlike brittle cast iron pipe, steel pipe does not easily break apart. It is, however, a deformable material that, like plastic, can be slit.

Once again, HammerHead engineers worked closely with gas industry professionals as they studied the requirements of this pipe slitting application. One focus was on the optimum taper of the tool. Another was on most effective placement of its cutting

Because slitting and installation operations follow the exact same path as the existing pipe, the pipe slitting method can be used in closer proximity to other services than other trenchless methods.

wheels. The factors are now precisely engineered. The first wheel of the splitting head scores the pipe. The next wheel, or wheels, follows in its track to completely sever the pipe wall. A final wheel ensures that any fixtures that might be encountered, such as clamps or bands used with repairs, are also cleanly severed. The pipe is free at that point for the expander to broaden the pipe, reducing drag on the next pipe as it drawn into place through the smooth hole.

The pipe-slitting method is not limited to size-on-size replacement. Use of larger expanders permit upsizing the existing line as much as twice the diameter of the original pipe.

STRIKE ZONE SAFETY

Slitting heads for plastic pipe ½-inch to 4 inches in diameter are typically designed for use with cable winches, with units ranging from 3.75 to 22 tons in capacity. Slitting heads designed for steel pipe and larger plastic pipe diameters are generally used with rod-pulling machines.

The cable winches and rod-pulling systems used in gas line replacement applications also required slight modification. Jurisdictions that permit joint utility trenching specify a minimum distance of required separation between gas lines and power lines. Gas line maintenance crews in one of the earliest demonstrations encountered discrepancies in "strike zone" tolerance so severe that at some points the two lines lay in contact with each another.

For that reason, all HammerHead winches and rod-pulling machines for gas line pipe slitting applications are equipped with Electrical Strike Identification. All HammerHead winches are available configured as pull-behind units or as track-carrier mounts.

SEEING IS BELIEVING

Plastic pipe replacement

A Georgia contractor added the pipe-slitting method to its capabilities while helping in the scheduled replacement of approximately 750 miles of plastic pipe for an Atlanta Gas Light initiative in the Atlanta metro and Northern Georgia area.

Installed between the years 1965 and 1983, the original plastic pipe was at or nearing the end of its useful life. Over time, urban sprawl and its associated infrastructure made replacement difficult. The contractor had been relying on its fleet of 13 horizontal directional drilling (HDD) rigs to complete Class 1 pipe installations – those providing at least 8 feet of separation between the bore for a new gas line and any electrically charged line in a distribution trench.

Those providing less than 8 feet of separation are Class 2 conditions. In Class 2 conditions, the contractor had routinely trenched down to replace the line manually. Of the 104 miles of pipe the contractor was to replace for this project in 2016, however, nearly half were Class 2 replacements. Sizes ranged from service lines 1 ¼ inches in diameter to 4-inch-diameter plastic mains. A more efficient way to do these Class 2 jobs was needed to stay on schedule.

The contractor assigned its fleet of HDD crews all Class 1 portions of the job and designated three 4-person crews to be its pipe-slitting specialists. This enabled the contractor to complete the entire 104 miles of scheduled replacement on time, as well as avoid the inconvenience to AGL customers of open-cut replacement methods. They also did it at a fraction of the cost of trenching. In fact, the extensive demolition and restoration that would have been required for some Class 2 sections of the project were not considered feasible.

Steel pipe replacement

Mark Maxwell, who has been an operator, technician and field consultant in buried pipe applications for more than 32 years, is a pipe-bursting and pipe-slitting field technician for HammerHead. Maxwell is often asked to demonstrate the method for project owners, engineers and gas line contractors on a "real-life" scheduled job.

One request was from a utility foreman with 20 years of experience in gas line infrastructure maintenance. He said the city's project engineers to

> *"Larger expanders permit upsizing the existing line as much as twice the diameter of the original pipe."*

date had favored "direct-bury and insert operations," digging up the steel gas lines to replace them with new pipe or hiring an HDD contractor to create a new offset pipe path parallel to the existing line. Crowded urban conditions rendered those methods infeasible, he believed, for some future gas line replacement jobs.

The foreman identified an ideal project for the demo presenting similar difficulties to those jobs. It was a 460-foot-long, size-on-size replacement of 4-inch steel gas line with 4-inch MDPE. The steel pipe lay 3 feet below a 14-foot-wide paved alley in cobble and stone fill. Several asphalt surfaces overlay the pavement's 8-inch cement base. In addition to the gas line, the narrow easement contained a water main, a vitrified clay pipe sewer line, and a conduit pipe containing phone lines running parallel to it.

This jurisdiction prohibited the use of HDD in such a crowded easement. The time and cost of full-length trenching and restoration in this location made it an ideal candidate for a pipe-slitting demonstration.

Maxwell arrived the night before to check the preparations. The HDPE had been fused up on the surface and a machine pit had been prepared. Pipe slitting operations started at 9 a.m. the next morning.

Although the foreman had known about the pipe slitting method most of his career, he had never seen an operation in person himself. As the tooling disappeared into the steel pipe, the foreman told Maxwell, "It's just amazing to see it in person. The quiet sound of it working as it takes off down the pipe, slicing through it like it's nothing."

The foreman said a job like this would typically have taken four to five days as a trenching job, not including full-length restoration of the 460-foot-long trench —compacting backfill, pouring a new base course and repaving the alley. They installed the new pipe and made the three connections to it in a single day.

The pipe slitting method also eliminated the extra steps sometimes required to decommission abandoned lines. The foreman said on open-cut replacement jobs, the crew must extract and dispose of the abandoned line. Their HDD jobs require them to purge the decommissioned line, fill its ends and sometimes even grout or slurry it. These steps to decommission a line adds time and cost to the project either way, whereas the pipe slitting method eliminates these steps because anyone who digs down to the 4-inch pipe in future excavations cannot mistake a decommissioned line from the active line within it.

INDEMNIFICATION

Alan Goodman, Market Development Manager for HammerHead, has been following the rising trend of indemnification requirements in the U.S. The assurance of immediate, visual verification gives the pipe-slitting method added value in jurisdictions requiring indemnification of abandoned lines. The amount of time that utilities are spending on both locating and verifying active and inactive gas lines comes with a significant cost. Slitting an inactive pipe helps verify its lack of use when excavating.

One utility provider had been upgrading some of its low pressure, high-density polyethylene (HDPE) main and service runs to a smaller diameter, higher pressure system. It had been slip-lining 1.25-inch (HDPE) plastic pipe inside the existing 4-inch HDPE. While slip-lining is one economical alternative to extraction and disposal, switching to the pipe-slitting method offered them same advantages with the added capability for size-on-size and even upsize replacement on other jobs.

EDUCATING THE INDUSTRY

Walk said, "We'd see many more companies specifying pipe-slitting coast to coast, but a lot of things have to be in place before a company is ready. It takes the right people, who see the need and can embrace a unique method that's new to them. It helps, too, if they're faced with replacing a larger quantity of gas lines rather than just a couple of hundred feet. When they are looking for a faster, more cost-effective method, then pipe slitting makes sense. Even then, it is a difficult task, trying to talk with every gas utility and gas pipe contractor in such a large industry about how the pipe slitting method fits their goals."

Goodman said HammerHead also makes education and training available in the pipe slitting method through HammerHead University, the world's first training facility solely dedicated to trenchless pipe applications. Open since August 2018, the facility is located at HammerHead headquarters in Lake Mills, Wisconsin. Natural gas industry professionals can receive hands-on instruction in the use of state-of-the-art pipe-slitting tools and equipment in true-to-life, simulated "jobsites" constructed within a climate-controlled environment. Participants who successfully complete the training receive certification for the course.

ABOUT HAMMERHEAD TRENCHLESS:

*Founded in 1989, **HammerHead Trenchless** provides the industry with the most comprehensive suite of precision-manufactured trenchless equipment and consumables for the installation, repair and replacement of pipes used in fiber, communication, water, sewer and gas underground infrastructure. HammerHead is part of The Charles Machine Works' Family of Companies, the Underground Authority. Each CMW company shares in its overall commitment to solving today's infrastructure challenges, offering solutions in all areas of underground construction.*

Twelve Best Practices to Avoid Pipeline Construction Environmental Shutdowns and Fines

By: Tony Finding, Brownfield Science & Technology, Inc. (BSTI)

Since 2005, innovative technologies such as hydraulic fracturing (i.e., fracking) and directional drilling (trenchless technologies) have made it possible to access valuable hydrocarbon resources from Pennsylvania's Marcellus and Utica shale deposits. Domestic natural gas production has increased to the point that Pennsylvania produces 19 per cent of the total output, which ranks #2 behind only Texas at 24 per cent.

The increase in natural gas production has triggered a demand for additional pipelines across Pennsylvania and the surrounding region to deliver product to market safely and efficiently. To construct a new pipeline, energy companies must navigate complex environmental regulations, permits, and technical obstacles. Any misstep along the way can result in costly operational shut- downs, public relations challenges, sizable fines and lengthy project delays.

Every pipeline installation location faces unique challenges. The purpose of this paper is to identify some of the more common causes of environmental, regulatory and permit violations that can result in work delays, fines and public relations challenges. The information below is presented in no particular order of importance. It is our hope that this paper can serve as a valuable guide to energy companies and pipeline operators as they plan and implement their pipeline construction projects.

1. ESTABLISH CLEAR LINES OF COMMUNICATION

Insufficient responses, reporting delays, inattention to permit details and work crew variabilities have all been factors in pipeline construction shutdowns and fines. Communication challenges become more complex when the project involves multiple contracting parties.

Governing authorities will not accept a lack of communication at the project level as a valid reason for not complying with permit conditions. Repeated failure to comply promptly with permits can risk a forced work stoppage, imposed fines, and/or additional legal penalties.

A robust Communications Plan should be generated and implemented at all levels of the project. A clearly outlined project personnel structure and chain of communication is vital to the Communications Plan. Timeframes and processes to report instances of non-compliance are also an important part of the plan. Managers and on-scene inspectors must be fluent in permit reporting requirements. They should also have the authority to obtain the information they need in a timely fashion. Enabling a process for field crews to identify and report potential issues to inspectors and managers can save valuable time and kick-start mitigation efforts. A self-regulating project can keep regulators from becoming overly involved with day-to-day oversight.

2. PROPER SOIL SEGREGATION AND RESTORATION OF OPEN-CUT WETLANDS

When open-cut trenching methods are used to cross wetland areas, soil segregation is important to maintain the integrity of the resource during restoration efforts. Specifically, wetlands underlain

To construct a new pipeline, energy companies must navigate complex environmental regulations

Thorough geotechnical investigations should be conducted before construction in all areas of planned HDD activity

by an impermeable "fragipan" soil horizon are at risk of drainage if not properly restored.

Wetlands with endangered and/or threatened species, such as bog turtle habitat, will likely require additional measures to avoid long-term impacts and might not be approved for open-cut crossing methods.

It is recommended that during initial trench excavation, a wetlands specialist or similarly- qualified expert is present to verify that soil horizons are carefully removed, segregated, and staged during construction. Following pipeline installation, complete and appropriate restoration of the wetland should be documented and approved by this expert.

3. PREPARE FOR WATER INFILTRATION WITHIN CONVENTIONAL BORE EXCAVATIONS

Conventional bore crossings typically require the excavation of pits to attain a direct bore path beneath the feature to be crossed. Storm water runoff and/or groundwater infiltration into the pits may necessitate significant water management measures including temporary settling and containment structures. Often, additional space is needed to construct water management structures. Special attention to permit conditions is important to avoid management and discharge violations. Additionally, the time

Important to maintain clean and orderly project access points

required to purchase/rent additional land for workspace, or to modify a permit, can result in delays of weeks.

It is recommended that a pre-construction evaluation of bore crossings take place to improve the understanding of the subsurface. This information can be used to design construction plans for crossings that add in contingencies for expanded dewatering and storm water handling requirements.

4. MAINTAIN EROSION CONTROL DEVICES (ECDS) TO PREVENT RUNOFF INTO WETLANDS, STREAMS AND OTHER WATERWAYS

Continual inspection and upkeep of ECDs is necessary to prevent runoff from the construction site into water bodies and other resources. Over time and multiple storm events, ECDs become less effective and need to be repaired or replaced to avoid unpermitted discharges to waterways and/or complaints from the public.

It is recommended that personnel be assigned to directly inspect ECDs on a regular basis as well as just prior to and after any storm events. Sufficient resources should be allocated to repair ECDs expeditiously.

5. MAINTAIN CONSTRUCTION OPERATIONS DURING PERMITTED WORK HOURS

Most municipalities and townships have ordinances specifying the permissible hours of operations for construction activities. Installation contractors are under pressure to make progress and may opt to work beyond the permitted timeframes. Especially in areas of increased public scrutiny, such actions may trigger noise and/or nuisance complaints from nearby residences. Habitual

> *A robust Communications Plan should be generated and implemented at all levels of the project.*

violations of such ordinances can risk temporary shutdown or revocation of local permits.

It is recommended that site supervisors be fully informed of and comply with all local rules and work timeframes. Daily work logs should always verify the actual hours of operation.

6. SYSTEMATIZE PROCESS FOR CHANGES TO CONSTRUCTION METHODS/TECHNIQUES

Often a construction method/technique change can make good tactical sense given in-field conditions or circumstances. However, such changes often require modifications to existing permits, which will necessitate regulatory review and approval.

Failure to follow permitted construction methods or techniques can result in the suspension of all permitted activities, extended delays, and fines for failure to comply.

It is recommended that a thorough and detailed Communications Plan be adopted, and all personnel be trained on its content to prevent these issues from impacting the project.

7. MINIMIZE INADVERTENT RETURNS OF DRILLING FLUIDS INTO UNCONTROLLED AREAS

Trenchless technologies, such as Horizontal Directional Drilling (HDD), utilize circulated drilling "mud" to advance a bore path through the subsurface often to cross underneath a major roadway or a sensitive environmental resource. Sometimes, the pressurized drilling mud will travel through natural subsurface pathways such as rock fractures and reach the ground surface. This is known as a "frack out" or inadvertent return (IR). IRs that enter waterways, wetlands, or ponds may be viewed as unpermitted discharges and subject to fines. In addition, IRs may cause property damage to nearby structures or roadways.

An IR can be quite visible to the surrounding community and often creates a public relations challenge. Exacerbating the problem, once an IR occurs, it will have a higher chance of reoccurring once drilling resumes due to the establishment of that preferential pathway.

It is recommended that a thorough geotechnical investigation be conducted in all areas that will likely involve HDD methods prior to actual drilling. Although nothing can detect all possible subsurface structure and fractures, the geotechnical investigation can predict areas where IRs would be more likely to occur. Reducing the length of an HDD bore to a minimum greatly reduces the risk of an unwanted IR. In high-risk areas or threatened or endangered species habitat, it may be advantageous to evaluate installation methods other than HDD.

Reducing length of HDD bore path to a minimum can greatly reduce the risk of inadvertent returns

8. MINIMIZE THE EFFECTS ON POTABLE WATER RESOURCES CAUSED BY TRENCHLESS TECHNOLOGIES

As presented above, HDD drilling mud has the potential to migrate through the subsurface and can enter nearby domestic water supply wells. Although drilling mud is non-toxic, effects can range from increased drinking water turbidity to complete infiltration with drilling fluids.

Additionally, a horizontal bore may intercept a local aquifer which could cause drainage back through the borehole and lower the groundwater level. If groundwater levels drop below well supply- pump depths, the local water supply may be lost. Affected users must be supplied immediately with alternative water sources and a long-term solution for their water needs will need to be addressed; possibly involving the installation of a new water well or connection to a publicly-owned water supply.

Municipalities and townships have ordinances specifying the permissible hours of operations for construction activities

Site supervisors need to be fully informed of, and compliant with, all local rules and work timeframes

As noted above, it is recommended that a thorough geotechnical investigation be conducted during pre-construction in all areas of planned HDD activity. In addition, all potable water wells in the area should be identified and monitored before, during and after construction activities.

9. PROMPTLY REPORT UNPERMITTED INCIDENTS/CONDITIONS

Accidental situations occur during pipeline construction that sometimes result in unpermitted conditions. Self-reporting a mistake or incident is inherently difficult, especially when on-scene workers are facing daily productivity pressures. Most permits have specified timeframes to voluntarily report occurrences of non-compliance. However, failure to report such occurrences within the timeframes can incur additional penalties to the project, including the stoppage of work.

It is recommended that thorough training of on-site personnel be conducted so that all personnel recognize when an unpermitted situation occurs, thereby minimizing the reliance on individual discretion. It is also recommended that a clear and timely process for reporting occurrences is adopted.

10. MAINTAIN CLEAN AND ORDERLY PROJECT ACCESS POINTS

Pipeline installation requires that work be conducted in remote areas. Access to the construction sites is often over temporary gravel roads originating from a nearby public road. Construction permits require that project access entries along public roadways remain clear of mud and debris that can be tracked along with construction vehicles.

Such access points may be the only point of interaction with the local community. Failure to maintain good housekeeping and public sensitivity in these areas can result in public nuisance complaints. Continued problems of this kind could risk the revocation of local construction permits.

It is recommended that sufficient cleanup personnel are dedicated to maintaining public roadways.

11. ADOPT A REALISTIC AND USEABLE PREPAREDNESS, PREVENTION AND CONTINGENCY (PPC) PLAN

In addition to IRs, unpermitted discharges to public waterways can occur due to fuel spills, hydraulic line failures, etc. In most

cases, a Preparedness, Prevention and Contingency (PPC) Plan will be required for pipeline construction sites. The PPC Plan will include best practices to avoid such spills; methods to document the cleanup measures taken; and how to prevent further violations of permitted conditions.

Having mitigation supplies on hand at the time of a release is an important and sometimes overlooked factor in response efforts. Lack of adequate procedures and/or cleanup equipment can allow spills to migrate to nearby waterways, resulting in permit violations, fines and work delays.

It is recommended that a PPC Plan be developed using practical and applicable techniques. All countermeasure equipment should also be readily available so that any job-site spills can be contained and cleaned up with minimal migration away from the loss area. The on-hand presence of cleanup and countermeasure supplies should be verified before construction activities begin.

12. BE CAREFUL IN THE SELECTION OF DRILLING FLUID ADDITIVES

Additives to drilling fluid can help overcome challenges during pipeline installation. Depending on the circumstance, it may be advantageous to adjust the pH, add bactericides, corrosion inhibitors, or other agents to the drilling fluids. The Pennsylvania Department of Environmental Protection maintains a specific list of approved drilling fluid additives.

In most cases, on-scene modification to a drilling fluid may make tactical sense but it does require approval. Further, use of an unapproved additive may be a permit violation and could result in fines.

It is recommended that all construction personnel be trained on the use of approved additives and that any reformulation of drilling fluids on the job site require supervisory level approval. Routine audits of drilling materials are also suggested.

The above summary represents our viewpoint, and what we have witnessed as the most common environmental-related reasons causing construction delays, job-site shutdowns, public relations challenges and fines. This paper is not a comprehensive list of all the possible issues that could be encountered during linear construction of pipelines.

ABOUT THE AUTHOR:

Tony Finding *is a Vice President of Brownfield Science & Technology, Inc. (BSTI) with 24 years of environmental consulting experience. BSTI provides a broad range of applied environmental sciences associated with environmental site assessments, permitting, regulatory compliance, predictive modeling, remediation, and litigation support. For more information visit www.bstiweb.com.*

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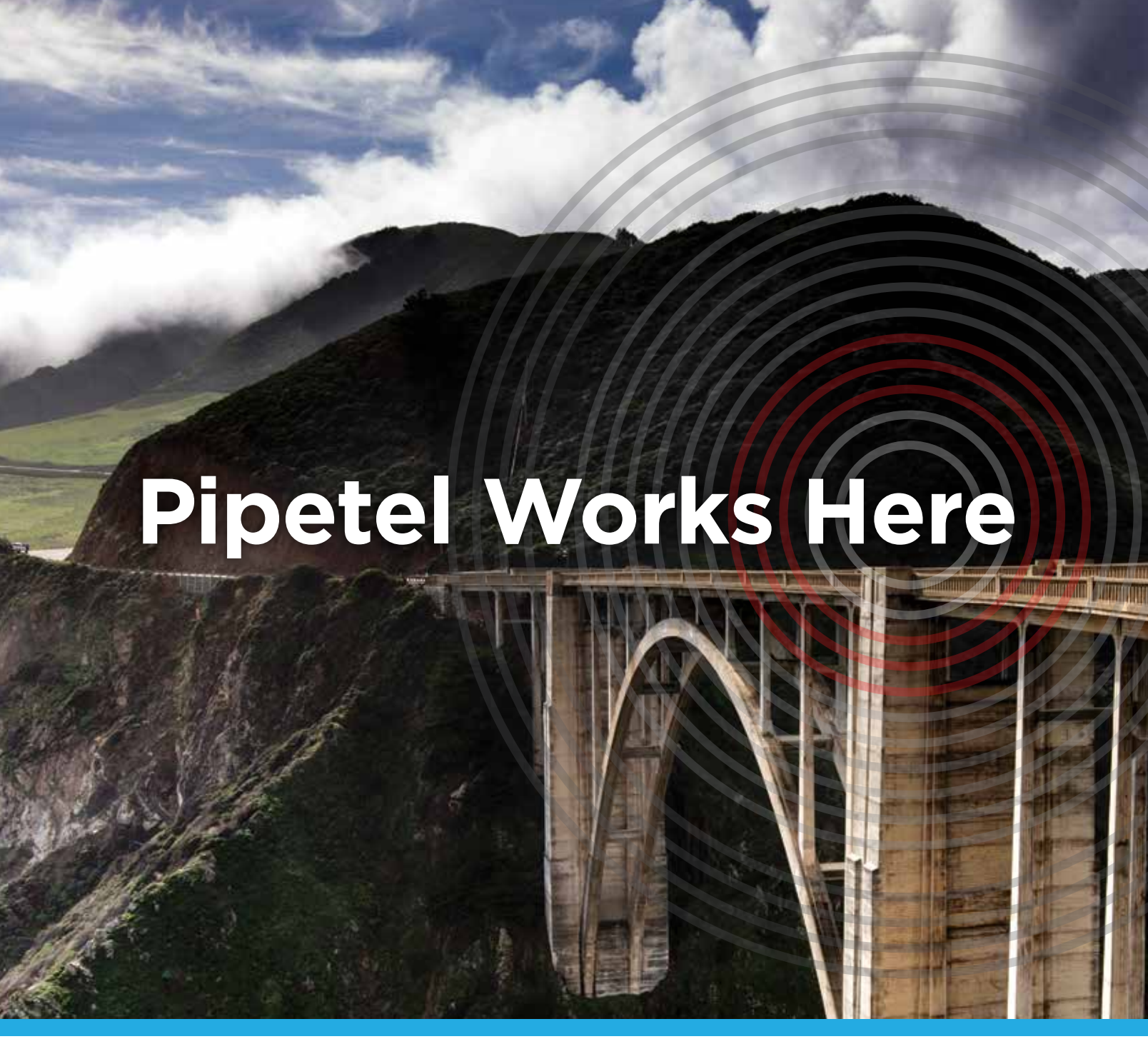

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