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2022

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AMPP Standard Practice for External Coating Systems

Trenchless methods such as HDD are optimal for challenging crossings where open trench installations are not practical. Because the pipe is subject to heavy forces and abrasion during pullback, damage to external coatings is far more likely with trenchless methods

Gas Main Extraction: Percussive Pipe Ramming

An Ohio utility had no choice but to replace 2,400 feet of an aging 12-inch steel gas main, however the right-of-way was very congested and no room was available for a new installation. The only choice was to extract the pipe. With limited space on either end of the pipe, pneumatic pipe ramming and static pull force were utilized to extract the old pipe and pull 2400 feet of new pipe into place.

Kentucky Utility Benefits from PHMSA Mega Rule

Details on the first high-pressure gas pipeline project using PA12 pipe, which is now approved for use under the DOT PHMSA Mega Rule. The Mega Rule approved the use of plastic pipe for a greater range of high-pressure applications in the U. S., eliminating the waiver process for PA12 and making it available for wider use.

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WELCOME MESSAGE FROM NASTT-NE CHAIR

Eric G. Schuler, P.E. NASTT-NE Chair

Welcome to the 4th annual edition of the NASTT Northeast Regional Chapter's Trenchless for Gas Infrastructure Journal! I hope that you find the content in this publication to be forward-thinking and practical. The NASTT-NE Chapter thanks the continued support of sponsor's for this crucial publication highlighting the gas industry.

We have new NASTT-NE Executive Committee and Board Members for the 2022-2023 term. This Regional Chapter is always evolving, growing, and learning from our past experiences relating to both Journal content and annual conference results. We are a volunteer-run organization and it takes a strong commitment from a select group within this industry to keep the "wheels-on-the-wagon" as we strive to provide sound educational and networking experiences for our 7-state region. As you read this magazine, I encourage you to get involved with our close-knit group if you are located within our region as we are always looking for individuals from the gas industry to get involved with our conferences and Journal content development.

Learning from the ***Past***, allows us to evolve for the ***Present***, which helps us grow for the ***Future***.

PAST (2021). The Northeast Chapter ended last year on a high-note with our first in-person conference since the COVID-19 pandemic hit our shores. The 2021 conference was held at the Historic Thayer Hotel at West Point NY; with approximately 100 attendees present for networking with peers/vendors and present for a full multi-track technical session agenda. UMASS-Lowell Student Chapter was integral in helping with on-site registration efforts and general conference support. Exterior demonstrations of various trenchless technologies has become a staple of our conferences; and many attendees braved the chilly NY November winds to join two contractors outside for their presentations.

Our three Journal publications (***Northeast Journal of Trenchless Technology Practices*** (2) and ***Trenchless for Gas Infrastructure***) in 2021 provided a great insight into industry trends and highlights within the region and beyond it.

PRESENT (2022). This is going to be an exciting year for the Regional Chapter as we are shifting our annual conference to Portland Maine for this November. We originally were planning on holding an annual conference in Portland back in 2020, but was forced into a cancellation due to the ongoing pandemic. Luckily, we were able to hold a spot on the Venue schedule for 2022 and are excited to bring our show to the northernmost state in our region. Our Conference Venue Planning Committee consisting of Bill Jeffery, Pat Ambrosio, and Tom Loyer are already full-steam ahead with getting us ready for this event. We will be releasing a detailed flyer later this spring highlighting conference details and "save the date" information.

We are looking for additional content for the Fall edition of our Journal! So if you have a good "lessons learned" topic or a project that you would like to highlight, please reach out to me or our Publisher at any time.

FUTURE (2023 & 2024). Our conference Venue committee of Jonathan Kunay and Claudia Law are evaluating venue options for 2023 and 2024. A short-list has already been developed and we anticipate securing a 2023 venue later this Spring or early Summer. An announcement on that location will be forthcoming.

> *"Learning from the **Past**, allows us to evolve for the **Present**, which helps us grow for the **Future**."*

As we move through 2022 and into 2023, the Northeast Chapter will be focused on driving interest in the region for No-Dig 2024 in Providence RI. We have a sense of pride in No-Dig being held in the Northeast Region; close to home for many of our members. This will be the first No-Dig in the Northeast Region since the Northeast Chapter was formed.

In closing, a special thank you to George Ragula (RagulaTech) and Andrew Pattison (A to B Publishing) for their tireless efforts pulling together these premiere publications. Thank you for taking the time to read this edition, and I look forward to seeing you in Portland this November!

Eric Schuler

Eric G. Schuler, P.E.
Chair, NASTT-NE

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WELCOME MESSAGE FROM NASTT CHAIR

Alan Goodman, NASTT Chair

As more utilities and resources move underground, trenchless technology becomes the obvious choice for underground infrastructure management. With smaller easements and congested or inaccessible areas, trenchless technologies offer minimal to no excavation and surface disruption. NASTT is focused on the transfer of technology with advancements in new technology. This then affects the way both contractors and utilities evaluate trenchless methods. Safety is a top priority for the gas industry, and the use of trenchless techniques is much safer than conventional construction techniques. Utilizing trenchless methods requires thinking outside the box in solving today's construction issues and challenges. When you consider that 50 percent or more of a utility budget is spent on construction, trenchless results in more reliability at lower costs. Knowledge of when and how to apply its use is the key to successful implementation. This is achieved through education and training.

As we know North America relies heavily on dependable sources of energy, yet the infrastructure that supports these utilities is at the end of its lifecycle. While natural gas and electrical utilities continue to provide a safe and reliable solution, they must continuously work to keep the energy flowing, regardless of any rehab, replacement, or new installation taking place. The ultimate goal is to reduce leak backlogs while also reducing CO2 emissions and equipment footprint.

NASTT is one of the fastest growing societies in North America comprised of engineers, contractors, municipalities, utilities, and others with strong beliefs in the practical, social and environmental benefits of trenchless technology. By partnering with American Gas Association (AGA) & Distribution Contractors Association (DCA), NASTT can bring the engineering community together to provide accurate designs and constructible projects. Our mission to advance trenchless technology is achieved through technical information dissemination, research and development, education, and training. NASTT strives to provide a voice for all sectors of the trenchless technology industry. For over 30 years, the all-volunteer members of NASTT have presented seminars and training on these "green alternative" engineering methods to North American communities.

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. As NASTT continues to share new technologies, the gas industry will benefit from enhanced safety, reduced excavation and emission, reductions in 3rd party damages, and the risk of human life to enter excavations. We regularly review and update our training materials and virtual/in-person courses. We are excited to roll out updated gas educational resources this year. For the latest information on upcoming events, visit our website at **www.nastt.org/training/events**.

We look forward to the events in the coming months to bring the underground

infrastructure community together. Please join us in Toronto, ON for the 2022 No-Dig North conference, October 17-19. No-Dig North is hosted by the Canadian Chapters of NASTT and offers two full days of training, education and networking. This is a must-attend event for anyone doing business in Canada. Visit **www.nodignorth.ca** for details!

Be sure to mark your calendars and save the date for the NASTT 2023 No-Dig Show in Portland, OR, April 30 – May 4. The city of Portland is a perfect location for our industry to come together to celebrate and educate with the theme, *Green Above, Green Below.* It is important that our industry is a steward of our natural resources, and we welcome the opportunity to provide a forum to learn about the latest in innovative trenchless products and services. Learn more at www.nastt.org/no-dig-show.

We welcome your feedback and questions! Please reach out to us at any time at info@nastt.org.

Alan Goodman

Chair, NASTT Board of Directors

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TRENCHLESS TECHNOLOGY PERSPECTIVE

Great Opportunity is Just around the Next Bend

George Ragula, RagulaTech Inc.

Welcome to the fourth annual edition of ***Trenchless for Gas Infrastructure 2022***, the NASTT-NE publication highlighting the use of trenchless technology applications in natural gas distribution construction programs. As shown in these pages, trenchless technology methods continue to provide a comprehensive set of alternative construction and rehabilitation techniques for all gas distribution infrastructure, offering particular value and relevance to America's aging inventory of gas pipelines.

Trenchless technology applications are now the fastest growing sector of the global construction industry, and these methods offer an immediate opportunity to make gas distribution systems more efficient while at the same time realizing significant reductions in overall 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. Gas leaks contribute considerably to greenhouse gas emissions and pipeline repair, replacement, renewal and rehabilitation techniques play a key role. Trenchless technology offers a solution to these challenges with innovative and cutting-edge approaches to seal leaks in the gas distribution system while preparing for the dawning hydrogen economy.

Over time, trenchless technology has evolved so that the most complex and challenging projects are where trenchless really shines, and where it can reap the greatest benefits and cost savings. By now, distribution company replacement programs using conventional construction methods are sufficiently advanced so that most of the easily accessible, least challenging leaking pipe has already been repaired or replaced. Conveniently located and easily accessible infrastructure has already been "cherry-picked", leaving the more expensive, and difficult to access, repair work for another day. There is a huge opportunity for trenchless technology to fill this void moving forwards, and seal up the more inaccessible portions of the aging inventory of leaking facilities.

Pipelines in remote or difficult-to-access regions like bridges, under highways and major thoroughfares, railroads, golf courses, waterways, newly paved roadways, heavily trafficked areas, etc. are considerably more difficult to repair and maintain than those in more accessible areas; detecting pipeline leaks in these regions is also difficult. That, combined with a low hazardous leak classification can mean leaks tend to remain active for extended periods of time. Such repairs are also considerably more costly than those in pipeline sections located in more accessible locations, and conventional construction equipment is more difficult and costly to deploy. Leaking pipe in remote areas can thus create significant challenges while accumulating safety, social, and environmental hazards that would have been mitigated much sooner if they had occurred in more accessible locations.

Various trenchless methods can be effectively applied as viable alternative solutions dependent on the specific environmental obstacles and terrain. Pipeline rehabilitation becomes a very attractive solution when one considers the money is in the hole, or in the case of exposed crossings, getting it installed in the first place at the time of bridge construction.

Pipeline renewal using CIPL for rehabilitation on pipelines in these outlying areas is demonstrably the best approach, yet ironically CIPL lining of cast iron and steel pipe remains the least understood trenchless method, despite being utilized on pipeline repair projects for more than 30 years. Today's increased inspection, repair, and replacement standards, and the urgent need to reduce GHG emissions, should bring this technology to the forefront when it comes to discussions on leak-proofing the gas pipelines. In fact, more intense testing on liner products for compatibility with hydrogen intermixed into the gas stream is slated to begin this summer.

As always, utilizing trenchless methods requires thinking outside of the box in solving both onsite construction issues and alleviating the pressing social and environmental challenges we face today. With all the easier pipeline-related work already "cherry-picked", it stands to reason that trenchless can play a more profound role in this area, while providing an economical solution and benefit.

Special acknowledgement and appreciation to the NASTT-NE Chapter, and its forward-thinking members and leadership, for sponsoring and promoting 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

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Proving and Improving Pipeline Technology for Twenty Years

Progressive Pipeline Management CEO Dave Wickersham Reflects on the Development of Trenchless Technology for Gas Pipelines

Since 2002, NASTT-NE Chapter member Progressive Pipeline Management (PPM) has been renewing natural gas pipelines from 12 to 42 inches along highways, bridges, railroad lines and urban environments. The Starline® Cured-in-place-lining trenchless technology is a proven, cost-effective method that extends the life of an existing pipeline by over 100 years. As they celebrate twenty years, Dave Wickersham, founder and CEO, reflected on the decisions that shaped the first twenty years and what he sees ahead in the gas pipeline renewal landscape.

A CALCULATED GAMBLE ON AGING GAS MAINS

Over twenty years ago, I was asked to help on a gas pipeline project in Philadelphia where the Contractor, Exelon Infrastructure, needed help with removing oil and potential PCBs from the line. They needed to remove the oil before they could "line" the 20-inch natural gas main. This was the very first time I witnessed the Starline® Cured-In-Place-Lining (CIPL) technology. A year later, Exelon was looking for an exit in the Starline license and I was immediately interested. Investing in it was a gamble, although calculated. Would the industry adopt the lining technology and capitalize on its ability to repair aging gas pipelines?

Back in the early 1990s first generation liners were making an appearance in the US from a technology transfer perspective. The technology was developed in Japan and was evaluated by The Gang of Five (5 US utilities consisting of PG&E, PECO, Keyspan, Con Edison and PSE&G) as part of a Gas Research Institute (GRI) R&D program. Actual installations took place for evaluation purposes in addition to independent laboratory testing conducted by GRI. The overall results were very positive, stimulated interest and confirmed its applicability for renewing natural gas pipelines. Fast forwarding to now, a number of key improvements and innovative technical advancements have been incorporated into the second generation liners, like the premier Starline® liner.

We secured an exclusive license for North America for Starline® from the inventor and patent holder, Karl Weiss of Berlin, Germany and began PPM in August of 2002. The first 10 years focused on understanding the technology, testing and fine-tuning how to utilize the equipment and approach projects. Our customers - PSE&G, National Grid, Con Edison and PECO Energy in Philadelphia, were willing to come with us. Our core team spent hundreds of hours understanding the capabilities, the limitations, the opportunities and use cases for utilities. The learning curve and drive to both prove the technology and improve it kicked in early and remains a cornerstone of our work. The gamble paid off, slowly. Years of testing eventually proved to have very positive results.

> *"Rehabilitating a leaking gas pipeline minimizes or eliminates greenhouse gas emissions while preserving the resource."*

R&D & INDUSTRY TESTING

Our team collaborated with industry experts at leading utilities focused on specialized gas pipeline issues. The natural gas industry has invested over $15 million in testing of the Starline liner and its capabilities at Cornell University, Battelle Labs with research partners including the Gas Technology Institute, NYSEARCH and PHMSA. Multi-year research projects were co-funded by US DOT & PHMSA. Research & Development Program: Technology Transfer, Demonstrations and Post-Mortem Testing of Cast Iron and Steel Pipe Lined with Cured in- Place Pipe Liners.

With additional extensive R&D and independent testing on rehabilitated pipe with the Starline technology, CIPL has a confirmed service life of 100-plus years. At first, CIPL projects focused on smaller cast iron and steel pipelines such as 12-inch diameter and less. We then moved up to 16-inch and 20-inch jobs. Starline® liner was developed specifically for lining high-pressure

gas pipes. It is capable of installation applications at a maximum allowable operating pressure (MAOP) of 99 PSI, 180 PSI and 350 PSI. This culminated with meeting two ASTM Standards for lining gas mains and services. Namely F2207-02 and F2207-06.

LARGE DIAMETERS & BREAKING WORLD RECORDS

The final Cornell studies with the DOT in 2014 and 2015 supported the 100+ year service life of an active liner. That endorsement opened PPM to lining projects that were much larger in diameter. After lining a 30-inch gas main, we secured the first world record lining project of a 36-inch cast iron gas main in 2017 with Public Service Electric & Gas (PSE&G) in South Orange, New Jersey. See the final project documents here. Research & Development Program: Technology Transfer, Demonstrations and Post-Mortem Testing of Cast Iron and Steel Pipe Lined with Cured in- Place Pipe Liners (https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=502)

Two years later, again with PSE&G in East Orange, N.J. we crushed our own world record for the largest size natural gas pipe to be rehabilitated with Starline liner. The 42-inch diameter cast iron gas main is in a highly congested area with multiple freeways, underpasses and a hospital. The gas line travels 80 feet directly down an embankment and then crosses under a major highway and back up the other side to street level.

Overhead view of the 42-inch drum, pit and transfer hose

There was no viable alternative for renewing these gas mains. In urban, historic and high-traffic areas where PPM is called in to solve a problem, the cost and disruption would be astronomical to dig up the old pipe and lay new pipe. To replace this section of pipe conventionally using open cut construction, would have cost millions of dollars and caused significant headaches and disruption.

SUPER-SIZED CHALLENGES

The move to larger-diameter pipes required an entirely different mindset and new advancements. Once the excavation holes are dug, there are four stages of a lining project. The inspection of the pipeline is done by CCTV. Then the lines have to be cleaned and prepared to be smooth and free of dust and grit. The GMZ's Guzzler vacuum trucks have a throughput of 5,000 CFM (cubic feet per minute.) To scale up, we invested in three trailer-mounted dust-collection machines from Rapid Prep with a throughput of 25,000 CFM. The dust collectors offer 5X the capacity for the same footprint.

> *"The beauty of CIPL is that it not only addresses the leaks that our customers have identified, but eliminates the ones that have not been identified."*

Lining and curing phases use a conversion drum developed with Karl Weiss GMBH in Germany, which owns the patent for Starline in Europe. Wetting out the liner involves mixing two-part chemicals. The mixed resin goes into the open end of the liner and spreads out through its full length by rollers while being pulled onto the pipe inversion drum. To handle the large diameter liners and be mobile enough to manage getting around city streets and intersections like the ones in New York City, we designed a mega sized drum.

Super-sized drum for large diameter lining

SHIFT FROM QUICK FIX TO LONG TERM STRATEGY

Lining has become a more accepted, day-to-day solution than just a one-off bridge crossing or something that's an emerging tech. It used to be a stop-gap, quick-response, band-aid fix for a specific situation like a bridge, a historic block or train crossing. We'd get the call from one of our gas clients, 'Hey, I've got 1,000 feet on this corner, give me a price, give me a proposal, come do it when you can.'

On the engineering side and planning, gas companies are looking at lining as part of their long-term strategy to manage leaking infrastructure. The cost savings with this technology compared to traditional replacement where you tear up a street and "rip and replace" is significant. Most of the big leaks and gas needs are in inner cities in the Northeast and metropolitan areas such as Chicago. They have limited resources which are getting increasingly squeezed by inflation, price increases and budget cuts. Raw material availability is unpredictable. Price increases, inflation, choked shipping lines and supply chains are conditions outside of our control.

Lining project in Chicago for 20-inch cast iron pipe dated 1861

To mitigate that, we're shifting to a longer contractual arrangement with our clients to plan ahead for lining projects over the course of three years. Investing in the raw material and the lining material now allow them to have the goods in the country ready to roll. Otherwise, they are victims of erratic pricing and an unpredictable supply chain. We are seeing more long term planning and execution. For National Grid, one of our long-term partners, we are doing rehabilitation projects "Turn-Key", with PPM engineering, a contractor partner for the excavation and pipework, and PPM lining as an all-in package. This has streamlined the process and costs for the Utility, and we see this as an opportunity to use this model with our other Clients.

EPA PIPES ACT REDUCING METHANE EMISSIONS

Important positive shifts are happening as the industry is serious about eliminating hazardous leaks and reducing greenhouse gas emissions. The PHMSA Pipeline and Hazardous Materials Safety PIPES Act of 2020 came means tighter regulations on leaking pipes. Pipeline operators need to address leaks and releases of gas as well as address replacement or remediation of lines known to leak. Lining is a better and more cost effective way to fix leaks and includes a hundred year capitalization that goes onto the books as assets. Rehabilitating a leaking pipeline minimizes or eliminates greenhouse gas emissions while preserving the resource. The beauty of CIPL is that it not only addresses the leaks that our customers have identified, but eliminates the ones that have not been identified.

TESTING HYDROGEN BLEND TO NATURAL GAS PIPELINES

Testing and R&D is underway to look at the effects of transporting natural gas and hydrogen blends in the same pipeline. AGA and DOT have work groups sponsored by PHMSA that include testing lining as a solution for hydrogen blend and transportation. It could reduce and make the transportation of natural gas safer, more efficient and greener. Part of the testing will be what happens to a gas pipeline that has already been lined with Starline. We feel good about the capability of the liner to withstand hydrogen gas. The liner composition could be changed if needed. We are involved with testing this year to address if a lined pipe has more resistance to leaking hydrogen than a normal pipe, and the appropriate levels of hydrogen/gas blends for liners.

CONTINUOUS FINE TUNING – THE SMART BOX!

The first twenty years brought many changes, but our focus stays the same. We challenge ourselves every day to find ways to line faster, safer and more cost effectively. One aspect is to reduce project costs for our crews as well as the Utility crews. During the lining project gas is off line. To help us move towards that goal, we've developed a Wi-Fi system that allows us to remotely monitor pressure regulation during the curing of the liner. When we line a gas pipe, we monitor the curing, look at the pressure curing

gauges and chart recorder in the hole. The old way was going back out for 2 hours of work with full crews to look at something that we typically know is fine. We do this for each day the liner cures, which may be 1 to 3 days or more depending on ambient temperature.

The "Smart Box" monitors the pressure of the line in real-time. Once we're in the curing process, we can remotely monitor the pressure in that line remotely. We can monitor pressure loss, temperature loss and can see the correlation between increases in temperature and decrease in temperature. It saves the client money, saves us money and time, and delivers better data. There are alarms and safeguards in place where we get a 9-1-1 code and an alert in the event of any anomalies. We are working closely with Honeywell and Verizon on the continued development of this powerful cost saving and data preservation tool.

MANAGING GROWTH AND RETAINING TALENT

Our company has lined over a million feet of pipeline – around 200 miles – of gas pipelines in 18 different states. Our Clients continue to see the benefits of the technology that PPM offers and our work also grows within each Client. These are natural gas pressure pipelines predominantly cast iron and steel. The growth will continue, we just signed a 10-year exclusive license renewal with Karl Weiss and re-invested more than $3m in capital equipment including two new CIPL pressure drums and replacing 70 percent of our fleet.

We have a strong and trusted team who have been with me all the way. These are folks who had kids after they started working at PPM (myself included!); then they were buying houses or moving to better homes to provide for their growing families. Now, their kids are going to college and they have maintained that PPM drive to continue to grow and achieve. Our employee retention remains very high, even throughout the pandemic. We are very proud of this achievement. It's a unique culture that we have fostered over the last 20 years and built a brand that our team and our clients are very proud of.

Finally, I would be remiss to not mention and remember Johnny Nelson, Ernest Woods, Phil Hoffer and Jean Rivard. Each played a critical role in our growth and development over the years and all left us much too soon. They remain a strong part of our PPM Family today and are with us in spirit on every project. God Speed boys. #PPMSTRONG.

PPM has a strong and trusted team that maintains the PPM drive to grow and achieve. #PPMSTRONG!

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Progressive Pipeline Management, Wenonah, New Jersey
Owner: David Wickersham
Founded: 2002
Employees: 150+
Service Area: National – But Home based in the Mid-Atlantic & North East.
Website: www.progressivepipe.com

AMPP Standard Practice for External Coating Systems in Pipeline Trenchless Crossings

By: Aida Lopez-Garrity, Mears Group, Inc.

BACKGROUND

It is common to encounter damage to external anti-corrosion coatings on pipelines due to abrasion and gouging during pullback in trenchless installations. The consequences of this loss of external corrosion protection on installed pipelines can be catastrophic and expensive.

Trenchless methods such as HDD are optimal for challenging crossings where open trench installations are not practical such as under rivers, sensitive ecological areas, roads, railroads, narrow easements or heavily populated and trafficked locations. Because the pipe is subject to heavy forces and abrasion during pullback, damage to external coatings is far more likely with trenchless methods than with open trench construction. Therefore, the places where coating damage is most likely to occur are the areas where the consequences of this damage can be the greatest due to environmental sensitivity and/or limited access to make repairs.

Given the growth in use of trenchless construction methods for natural gas transmission and distribution systems, it was vitally important that a framework of guidelines was developed specifically for reducing external pipe coating damage during trenchless construction. The benefits of this are twofold. Pipeline integrity will be improved by providing coatings that will not be damaged during installation and costs will be reduced by considering these guidelines in the design stage.

NACE EXTERNAL COATING STANDARD PRACTICE PURPOSE

The Pipeline Hazardous Materials Safety Administration (PHMSA) oversees the regulations for natural gas pipelines in the US. The Code of Federal Regulations (CFR) provide the most basic requirements for pipeline design, corrosion protection/prevention, and integrity management. None of these regulations govern coating damage during trenchless construction.

The purpose of the **AMPP (Association for Materials Protection and Performance) (previously known as NACE National Association of Corrosion Engineers – International) STANDARD PRACTICE SP21443-2020 "Coating Systems (External) for Pipeline Trenchless Crossings**" is to provide guidance in the selection of the appropriate coating systems suitable for various trenchless crossings, and to outline standards of practice in order to minimize and identify damage to external coatings. It will provide the most current technology and industry practices for the use of coating systems (external) for trenchless crossings such as directional drills, road bores, and areas where extra abrasion resistance is required.

In the **Standard Practice** document, "Trenchless Crossings" are defined as subsurface construction methods for installing pipelines that require minimal excavations, such as Auger Boring, HDD, Microtunneling, or the Direct-Pipe method.

The **Standard Practice** establishes and provides:

- Guidelines for the minimum requirements for the proper application and inspection of coating systems for trenchless crossings.
- Identifies inspection and repair techniques to achieve the best application of plant and field applied coating systems.

The document is a collaborative effort and was prepared under STG 03 (TG 352). TG 352 consists of a group of users, service providers, and coating manufacturers. There are a number of reference standards that support its requirements.

EXTERNAL COATING MATERIALS & APPLICATION CONSIDERATIONS

Coatings used within the **Standard Practice**:

- Fusion Bonded Epoxy FBE
- Liquid Epoxies
- Polyurethane
- Epoxy-Urethanes
- Extruded polyethylene (Shrink sleeves)
- Polyolefin
- Three Layer Coatings (Three-layer polyolefin coatings (3LPO) or High-Performance Powder Coatings (HPPC) Reinforced Polyolefin Shrink)
- Concrete

Applicable girth weld coating systems are also provided in the standard practice.

These coatings have been grouped in a total of eight (8) coating systems and guidelines are provided on how to qualify, test and apply each abrasive coating. See Table 1.

Table 1. Systems for Abrasion Resistant Coatings

Coating System	Coatings
System 1: dual-layer FBE (corrosion coating and abrasion-resistant overcoat)	Dual Powder FBE
System 2: One-layer FBE as a corrosion-resistant coating with an abrasion resistant overcoat (ARO)	FBE Powder + Polyurethane outer layer or FBE Powder + Liquid Epoxy/Polyurethane or FBE Powder + Liquid Epoxy
System 3: One-layer Liquid epoxy-polyurethane, or one-layer liquid epoxy	Single-layer of liquid epoxy-polyurethane (100% solids) or single layer liquid epoxy.
System 4: One-layer Liquid Epoxy with an ARO	Single-layer of liquid epoxy + polyurethane outer layer
System 5: One-layer epoxy with extruded polyethylene overcoat	Epoxy-primed pipe (liquid or powder) + polyethylene outer sheath
System 6: Three-layer system: Three-layer polyolefin coatings (3LPO) or High-Performance Powder Coatings (HPPC) Reinforced polyolefin shrink	Powder or liquid epoxy primer + powdered copolymer adhesive + powdered or extruded polyethylene outer layer, or Powder or liquid epoxy primer + polyolefin adhesive + tough polyethylene outer layer
System 7: Concrete over other coating	One layer of any of the following + one layer of concrete: Powder FBE Liquid Epoxy Liquid Epoxy/Polyurethane Liquid Polyurethane Extruded Polyethylene
System 8: Applicable girth weld coating systems	Single/Dual Powder FBE Liquid Epoxy Liquid Epoxy/Polyurethane Liquid Polyurethane Extruded Polyethylene Heat Shrink Sleeves

Selection of the proper anti-abrasion coating is important because it protects the corrosion resistant coating of the pipeline underneath. Surface preparation depends upon the specific coating system employed, and the manufacturer's recommendations for application and curing temperatures. In general, the pipe surface needs to be free of oil, grease or contaminants. In addition to gouge and wear resistance, it is also important to have good adhesion between the anti-corrosion coating and the anti-abrasion coating.

There are a number of factors to consider when selecting coating systems including:

- Pipe size and weight or wall thickness
- Amount of pipe to be coated
- Availability of coating materials and/or applicators
- Ambient conditions
- Type of soils (rock, sandy, etc)
- Girth welds coatings
- Bend Radii, diameter, length of bore
- Buoyancy control conditions

It is important to have documentation from the coating system supplier including handling and storage information, code compliance, certifications and material qualification requirements. Specific guidance for the application and recommended thickness of each type of coating system is outlined in the **Standard Practice**. The S**tandard Practice** also provides guidance on which other testing standards will be applicable based on the selected coating system, such as: AMPP SP0394 "Application, Performance, and Quality Control of Plant-Applied Single-Layer Fusion-Bonded Epoxy External Coating", CSA Z245.20/Z245.21 "External Fusion Bond Epoxy Coating for Steel Pipe/External Polyethylene Coating for Pipe", and many others.

"The abrasion resistant coating (ARO) coating is used in conjunction with cathodic protection to provide a corrosion protection system for the steel line pipe. In most cases the abrasion resistance coating (ARO) has been designed to have some degree of flexibility, impact resistance, good adhesion to the steel substrate and the corrosion resistant coating, some degree of moisture permeation resistance, and compatibility with the cathodic protection system."

TRENCHLESS CROSSINGS BEST PRACTICES

A number of existing practices and technologies allow for ensuring the effective long-term integrity of Trenchless crossings, including trenchless crossings process or HDD installation practices, monitoring and inspection practices, and protective coatings and CP practices.

FIG. 1 Directional Drill

FIG. 2 Implementation of Best Practices

The single most often overlooked need is that of proper inspection and monitoring of the protective coating integrity during and following the completion of the drill. It is at this stage that decisions can be made regarding any special needs for supplemental CP to overcome an inordinate magnitude of coating damage. It is at this stage that CP designs can be modified to ensure the efficacy of corrosion control for the totality of the trenchless process or HDD. The **Standard Practice** provides guidance on how to inspect the pipe before and after installation including:

- Inspection and Measurement
- Coating thickness for field applied systems
- Holiday detection
- Repairs

The first point of coating inspection for trenchless crossings or HDD is the actual inspection during the application process at the coating mill. Applied coatings should then be further tested (utilizing industry accepted standards) for holidays, adhesion, gouge resistance, abrasion resistance, flexibility, penetration resistance and impact resistance. The test data should be readily available to any customer intended to purchase.

Further coating inspection must be completed prior to installation. In locations where the geological formations prove to be challenging to any trenchless crossing process or HDD installations, some practices involve pulling additional joints of pipe through the HDD to determine feasibility of pulling the remaining pipeline through. It should be noted a single joint pull-through will not represent the same loading and bending forces nor will it have a weld cap associated with the girth welds. This should be considered on those HDDs where rock formations or other objects might be encountered in the HDD that could possibly affect the condition of the coating.

Shear disbondment is another major concern from bending thick inflexible coatings. The challenge becomes balancing gouge resistant coatings to adequately address these damage mechanisms since they are usually not very flexible. The use of a sacrificial pipe segment on front of pullback through the borehole is recommended to properly evaluate coating damage and any potential mechanical damage.

In reality, significant variations in coating quality (mainline vs. HDD) can cause current distribution challenges that manifest in the form of over protection or under protection along the pipeline. Over protection can cause cathodic disbondment and blistering, while under protection can exacerbate external corrosion.

Current distribution can vary as soil resistivity changes from rock to deep bores which can impact CP requirements for shallow vs. deep sections and for segments surrounded by low resistivity drilling muds. Corrosion control monitoring using surveys is key, combined with electrical isolation of HDD piping segments using insulators. Such segments can be protected differently than main line pipe. This can mitigate over/under protection issues and provide overall improved current distribution.

Recommendations of best practices moving forward include:

a) The long-term integrity of an HDD crossing is supported by the combination of an integral external pipeline coating supplemented with effective cathodic protection.
b) Applied coatings should be tested (utilizing industry accepted standards) for adhesion, gouge resistance, abrasion resistance, flexibility, penetration resistance and impact resistance.
c) Coating Quality testing should be considered for all new HDD crossing to establish a benchmark of the effectiveness of the coating in the bore and to identify any special requirements for CP.
d) A careful visual inspection should be made of the first one or two pipe joints at the exit location.
e) Special CP design considerations may be necessary depending on the length, depth and geological formations in the bore. These may include linear anodes or dedicated CP systems on either end of the bore.
f) Additional monitoring tools including the use of coupons and/or reference cells installed parallel to long or deep crossings may be required to adequately determine the efficacy of the CP system.
g) Baseline ILI assessments are beneficial for the purposes of identifying mechanical damage which can be differentiated from metal loss associated with corrosion and for the purposes of Run-to-Run analysis to establish corrosion growth.

CONCLUSION – A LOOK AHEAD

Document published July 27, 2021, and is active now.

Effective processes for determining appropriate integrity management strategies and technologies, during installation and for

the life of the pipeline, ensure the success of a trenchless crossing or HDD crossing.

The AMPP Standard Practice "Coating Systems (External) for Pipeline Trenchless Crossings", provides a guidance for a selection of the most appropriate coating systems that will exceed the standard performance tests.

While the design requirements and installation considerations of a trenchless crossing or HDD are keys to a successful installation of a crossing, factors such as coating selection and external corrosion control with effective monitoring are keys to the long-term integrity.

ABOUT THE AUTHOR:

Aida Lopez-Garrity *has forty one years of experience in corrosion and materials engineering and the application of pipeline integrity measures to buried pipelines, compressor stations, and petro-chemical plants. She has managed programs in all aspects of Direct Assessment, Cathodic Protection, corrosion monitoring, welding, protective coatings, in-line inspection, NDE, and structural integrity. Aida is the NACE 2018 Russell A. Brannon Award Recipient the signature award of the AMPP Association for Materials Protection and Performance (formerly NACE).*

Gas Main Extraction:

Percussive Pipe Ramming Pulls (and Pushes) it's Weight

By: TT Technologies

Midwestern Contractors extracted 2,400 feet of 12-inch steel pipe utilizing a combination of pneumatic pipe rammers and static pull force

Pipe extraction is not a new process, but one that has been refined over the last 20 years. Through the combination of several techniques and tools, including pneumatic pipe rammers, contractors have become skilled at removing significant lengths of pipe from the ground.

On a recent project in Ohio, a 12-inch diameter steel gas main that had been in service for many years, began showing signs of internal and external problems. The owner had no choice but to replace 2,400 feet of aging pipe. The right-of-way corridor was very congested, however, and no room was available for a new installation. The only viable option was pipe extraction. The project contained a high degree of risk and required technical expertise.

Pipe Ramming Specialist Rick Melvin from trenchless equipment manufacturer TT Technologies, Aurora, IL, provided technical consultation on the extraction project. According to Melvin modern pipe extraction was in part developed through pneumatic pipe ramming HDD Assist methods. He said, "You'll find pipe rammers on HDD projects all the time. Typically they are being used in an HDD

On the pull side of the project, the pneumatic rammer was used in conjunction two the D8 CATS and a 10:1 block system. Grundoram pipe rammers from TT Technologies were used for the percussive force

Assist method to install the pipe and overcome hydrolock. But pipe extraction has also been part of this process. For example, when a drill stem breaks a ramming tool with a specially fabricated sleeve can be used to extract or retrieve that stem by applying percussive force.

"The process is a bit more complicated for a full pipe extraction, especially one that's 2,400 feet long and has been in the ground for a long time. However, for the project, Midwestern Contractors [Elburn, IL] was able to extract the 2,400 feet of heavy wall pipe, weld and hydro-test a new pipe string and pulled it in behind the old in about four weeks. That's impressive."

Midwestern Contractors has been installing piping systems for the oil and natural gas industry for over 60 years. During that time, Midwestern Contractors has grown and kept pace with the industries it serves. Midwestern Contractors has built a reputation for quality work, an experienced workforce and quick response. The company has been successful in staying ahead of the fast paced changes in the natural gas and refined products industry. Projects like the pipe extraction in Ohio demonstrate the contractor's expertise and skill.

PIPE EXTRACTION PROCESS

Extracting 2,400 feet of 12-inch steel pipe required significant planning. According to Melvin, the process is somewhat of a balancing act.

Melvin said, "Tension by itself would not be able to move the steel pipe or overcome the friction forces that hold the pipe in place. That's why on projects like this, extraction is about combining forces in a way that meet the requirements of the jobsite conditions.

First, you have pulling force on the front end of the pipe which can be generated in a number of ways, through a directional drill, excavators, etc.

"Second, you have percussive force typically generated by a large pipe rammer or combination of pipe rammers. The percussive force can be applied on the back end of the pipe, the front end of the pipe or both. Balancing the percussive and pull forces is the key to successful extraction."

Pull force prevents the pipe from reverting to its original position and allows any movement to be maintained when applying percussive force. This combination of a point force combined with a steady pull actually imparts movement to the pipe mass and once in motion it becomes easier to maintain the movement.

Each extraction project is unique with many variables determining the amount of pulling force and the requirements for the size of the pipe rammer. Melvin said, "There are a variety factors that you need to keep in mind when planning a pipe extraction. What is the quality of the existing pipe? What's the diameter, wall thickness, grade of steel? Is there a pipe coating? What type of soil are we dealing with? Are there ground water issues? That's just the beginning. You have to breakdown the jobsite and anticipate issues in advance."

For the Ohio extraction project two 24-inch diameter pneumatic pipe ramming tools, one on each end of the pipe string, two five-part steel block and tackle units on sleds, and two D8 CATS, applying a combined force of over 186,000 pounds of force were utilized to extract the pipe.

ON THE JOB

There were space constraints on each end of the project. On the push end of the pipe string or launch pit, the pneumatic pipe rammer was supported by track hoes and guided towards the entry point for the first 40 feet into the launch pit. The launch pit was excavated in a way to serve two purposes. The first was to allow for the needed alignment between the pneumatic rammer and the angle of the pipe. The second was to create a containment pit for bentonite drilling mud to coat the pipe as it entered the ground.

On the pulling end, or exit pit, the pneumatic rammer was supported and positioned at the optimum angle by two track hoes moving in conjunction with the pipe, as the D8 CATS and the 10:1 blocks applied pulling force. The space was extremely tight and only allowed for the extraction of one 40-foot section of pipe at a time when the 10:1 blocks were used, and 90-foot section of pipe when the pipe was pulled directly with the two CATS.

The 10:1 block system provides smooth and incremental pulling and allowed for continuous monitoring from a load cell. Once the existing pipe was free of the initial friction force, pipe movement began and the extraction force rapidly diminished to 52,000 lbs. as the pipe was withdrawn.

Melvin said, "The pipe rammers were only used at 25-30 percent of full power.

A containment pit for bentonite drilling mud to coat the pipe as it entered the ground was created on the push end of the project

The pneumatic pipe rammer can be varied from 50 to 180 strokes per minute. Throttling the frequency of the pneumatic rammer applied percussive force to the pipe and transmitted energy through the pipe and into the old drilling mud and soil. The percussive force helps to activate the drill mud and reduce friction between the pipe wall and soil interface. Combined with the constant pulling force the pipe overcame the wall friction and started to move."

At the 40-foot mark in the exit pit, the rammer was disconnected. The section of old pipe was cut and removed. The rammer was brought back to the stub end of the pipe, reconnected and the process was repeated. At the launch pit, the process was similar as the pneumatic rammer was disconnected from the pipe. A new joint was welded on, the rammer was reconnected to the new joint and the process repeated.

At the point where 160 feet of pipe had been extracted, the pneumatic pipe rammer was removed from the pulling end and the D8 CATS pulled directly on the string and removed it in 90-foot sections. The force required to pull the entire pipe was steadily decreasing from about 200,000 psi to 86,000 psi. and then to 52,000 psi. At the launch pit, when the new string was welded on the pipe rammer on that side was no longer needed. The process was repeated

The contractor was able to extract the 2,400 feet of heavy wall pipe, weld and hydro-test a new pipe string and pulled it in behind the old pipe in four weeks

until all 2,400 feet of new pipe was in place.

Melvin said, "This was a particularly challenging extraction. Midwestern Contractors operated at a level that was exceptional. Their knowledge and skill made this project a success."

ABOUT TT TECHNOLOGIES:

TT TECHNOLOGIES

For more than 45 years, TT Technologies has been the worldwide leader in trenchless technology. Each year, more trenchless sewer, water, gas and electric rehabilitation and replacement projects are successfully completed with trenchless equipment from TT Technologies than any other. TT Technologies is the leader in trenchless!

Kentucky Utilility Benefits From PHMSA Mega Rule

First High-Pressure Project On Record Wins Industry Award

By: Plastics Pipe Institute, Inc. (PPI)

Two 750-foot-long sections of pipe were installed with HDD

A high-pressure gas pipeline completed by Henderson Municipal Gas (HMG) utilized pipe made from polyamide-12 (PA12), which is now approved for use under the U.S. Department of Transportation's Pipeline and Hazardous Materials Safety Administration (PHMSA) Mega Rule. The pipe is rated at 200 psi, which can accommodate the pressure range HMG required.

The multi-stage project saw a total of 2,720 feet of the six-inch SDR 13.5 pipe manufactured by Teel Plastics, Inc. (Baraboo, WI) installed using trenching and horizontal directional drilling. The project won the Plastics Pipe Institute's Energy Piping Systems Division Project of the Year award for Teel. PPI is the major North American trade association representing all segments of the plastic pipe industry. The association's annual awards program recognizes projects and members for exceptional contributions to the industry. Submissions in the association's divisions are reviewed, evaluated and voted upon by the PPI members.

"This project marked the first PA12 installation under the PHMSA Mega Rule, which accepts PA12," stated Randy Knapp, Ph.D., engineering director of the Energy Piping Systems Division of PPI. "Prior to being incorporated by reference into the federal code, PA12 projects would require a special permit. Because an application would have to be filed for each individual project, the process was quite difficult and lengthy, requiring a coordinated effort between the pipe manufacturer, system designers, installers, state regulators and PHMSA. Naturally, this would take a lot of time and people. That is why the PHMSA Mega Rule is significant and highly beneficial to utilities and their customers."

PA12 is an innovative material suited for high-pressure gas applications and has been used internationally for years. In the United States, however, PA 12 had previously been installed only via special regulatory waivers. The Mega Rule approved the use of plastic pipe for a greater range of high-pressure applications in the U. S., eliminating the waiver process for PA12 and making it available for wider use.

HMG was drawn to PA12 pipe with a 200 psi rating, primarily for its ease of installation compared to steel. Considering all budgetary criteria for the project, the total installed cost for using the pipe was less expensive than steel. Plus, unlike steel, PA 12 does not require cathodic protection, saving extra labor, materials, and long-term monitoring.

Pipe segments are fused easily in the field

"The PA12 fusion process was much easier and faster than welding steel would have been, saving HMG significant time and labor," stated Owen Reeves, P.E. (PA) gas system director of Henderson Municipal Gas.

Located on the Ohio River, west of Louisville, Henderson has a population of nearly 30,000. Established in 1859, Henderson Municipal Gas is the fifth oldest system in the United States. It serves the natural gas needs of the City of Henderson, adjacent areas and the City of Corydon. It has 8,400 residential, 1,100 commercial and 50 industrial customers. Annual throughput is 3.1 billion cubic feet.

HMG installed the pipe through an industrialized area of the city. "The county and the city were able to acquire a grant to widen the roadway in one of our industrial sectors," Reeves explained. "A lot of trucks and cars go up and down that road, and it was in poor condition. The issue was that the gas line was on the edge of the existing asphalt, and we didn't want to be underneath the new, widened road.

"The existing line was steel, epoxy-coated pipe, which has been our traditional choice in the past if we were going to be above 125 psi," he continued. "Steel pipe is what anyone would use for our conditions. Our concern was that there are probably a dozen or more building entrances on one side of the road and a dozen or more on the other side of the road. The logistics were that some of these companies run three shifts, a lot of vehicles run up and down that road. The problem was how were we going to stage the epoxy steel pipe for welding, get it connected, x-rayed and get it in the ground. We didn't want to block vehicles from the businesses.

"In this area, we operated at 90 psi with the prior pipe. We wanted the ability to go up to 200 psi in case there's future expansion. We did consider 250 psi using PA12, but that pipe was significantly more money and we really didn't need the extra pounds of pressure, so we stayed at the SDR that allowed for 200 psi MAOP."

Reeves said that PA12 and PA11, had been talked about in the industry for a long time, and reflected, "It sure would be nice if we could get pipe that would fuse together in a faster manner. That would make the whole job much easier'.

"We called our state inspectors and said we would like to use PA11 or PA12," he explained. "And because it had been used in other places, we asked them to take that into consideration because they had made special provisions for two other projects in the state. Those, however, were both four-inch projects. We wanted to increase to six-inch pipe as well as the higher pressure. They looked into it and said 'yes, we can likely grant you a special exemption, but it will take 18 months for you to get it'.

"So, we decided to start the process and called around to get educated about the two different products. This included Teel and also the PA12 resin producer, Evonik. The bottom line is that PA11 comes from castor oil, which might be in limited quantities and there was really only one manufacturer in the United States at that point in time, and they weren't producing six-inch. We felt the future would be with the PA12 so we decided to go with the PA12 pipe, if our timeframe could be met."

"PA12 is a newer material in the United States," explained PPI's Knapp. "And this project serves as an example of where and how PA12 can be a beneficial alternative to steel for future projects. It demonstrates that PA12 is a viable option as a high-strength alternative to steel that can save customers significant time, labor, and costs during installation."

"At the eleventh hour, PA12 pipe was approved by the PHMSA Mega Rule," continued Reeves. "So, that's what you call perfect timing because we had been stalking this project for about two years, and were within a month of a 'go' 'no-go', as far as whether or not we would be able to use PA12.

"The project went ahead on the fact that you can fuse PA12 together just like polyethylene (PE) which we've been

Installation went smoothly and none of the weak links or pipe were damaged

using for quite a while. It's a little longer in time for the PA12, but the same type of equipment, same principle. That's what made us go that route. We had three directional bores, one which connected two 750-foot-long sections of pipe and one that went across the road. The rest was trenching by a trencher and some areas we used a backhoe to excavate. We did a total of 2,720 feet."

Teel, one of only two PA12 gas pipe manufacturers in the United States, provided a specially designed "weak link" mechanism to aid in the installation. These were used in each section of the pipe to help ensure that as it was pulled through the holes, the links would stretch or break in the event of a snag instead of stressing the pipe itself. The installation went smoothly and none of the links or pipe were damaged.

"This project demonstrates the benefits and costs savings of a new plastic pipe material that could open new opportunities to plastic pipe manufacturers as they seek to offer viable alternatives to steel," offered David Fink, president of PPI. "It serves as a feature project that can be referenced in seeking the wider acceptance and prevalence of PA12 now that certain legal barriers to its installation have been removed. In short, the success of Henderson's project helps blaze a trail for an innovative plastic pipe product."

With a 200 psi rating, PA12 pipe benefitted HMG as a steel pipe alternative. "Pulling steel pipe, the bored holes would have been more difficult," Reeves stated, "and the welding required to join steel pipe sections would have required additional manpower and prolonged time in the field. The PA12 butt fusion process HMG used was much easier and faster, saving HMG significant time and labor."

Reeves estimated that welding steel pipe would have taken two to three weeks during the first phase of the project, while the PA12 butt fusion process took only about three days. Each fusion required only about an hour to complete, including alignment and placement.

"The job came in on time and under budget. We saved on the welding time that would have been done in the field and so we viewed it as a very good project. I would use PA12 pipe in a heartbeat anywhere under conditions that are more than 125 psi, less than 250 and where you do not have very many valves in the line." Reeves stated. "If you're putting in a main header, and going a long ways to serve a city far from existing infrastructure, I would not hesitate to use it."

ABOUT PPI:

PPI Plastics Pipe Institute The Voice of an Industry.

The Plastics Pipe Institute, Inc. (PPI) *is the major North American trade association representing the plastic pipe industry and is dedicated to promoting plastic as the materials of choice for pipe and conduit applications. PPI is the premier technical, engineering and industry knowledge resource publishing data for use in the development and design of plastic pipe and conduit systems. Additionally, PPI collaborates with industry organizations that set standards for manufacturing practices and installation methods.*

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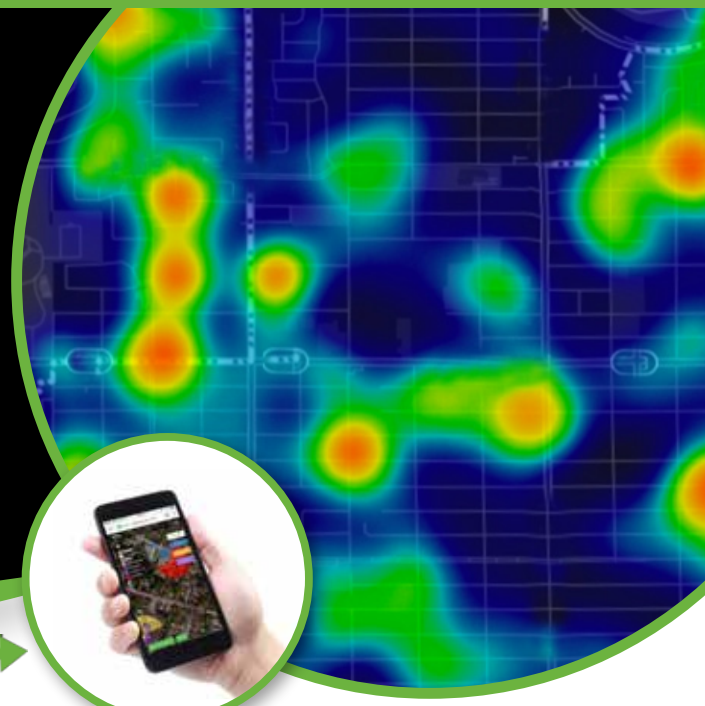

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National Grid Distribution Integrity Management Program

PPM Turnkey Approach Utilized Successfully by National Grid

By: Claudia Law, Progressive Pipeline Management

TURNKEY OVERVIEW

Progressive Pipeline Management is a full-service contractor and team of highly skilled infrastructure renewal specialists. The company has been committed to improving the safety and longevity of pipeline infrastructure since the company's inception in 2002. PPM's primary expertise is trenchless technologies to restore aging, damaged or leaking underground infrastructure, including pipelines of all types and sizes. We are the North American licensee in the US for the Starline® Cured-in-Place-Lining (CIPL) technology for rehabilitating pressure pipelines of all types. PPM tackles some of the most pressing problems in the pipeline renewal industry with proven results.

Extensive R & D and independent testing on rehabilitated pipe with the Starline® technology has confirmed a service life of 100-plus years. The natural gas industry has invested over $15 million in testing of the liner and its capabilities at such esteemed institutions as Cornell University, Battelle Labs, ASTM, NYSEARCH and PHMSA.

A noted accomplishment is our partnership with National Grid on their Distribution Integrity Management Program which includes a 5-mile yearly commitment for the next 20 years spanning from New York through New England. Our "Turnkey" process was born out of necessity and has given a much-needed solution to National Grid during their heaviest construction seasons. In our industry, competing priorities and emergency maintenance are barriers we have to navigate. PPM's solution was to create a "Turnkey" project process that would allow us to alleviate

our client's resources by supplementing with our own labor force. PPM employs a certified excavation subcontractor to complete all of the excavation and pipe preparation work that National Grid would have previously been responsible for. For the past 10 years, we have fine-tuned our approach alongside National Grid in order to ensure superior quality of our operational and project management.

Turnkey Project Process

Our turnkey approach is currently successfully utilized by National Grid New York and National Grid New England; however, our turnkey concept can be modified to meet requirements of any client. Below is PPM's project process explained:

- **Preliminary Review**

During the beginning stages of the project the utility will site select a segment of pipe that needs renewal based on a leak prone survey. Here is where the location, diameter, pipe material, MAOP and start/end points will be determined.

- **Service Concentration**

The utility will then provide all information and records displaying if there are any known services on the pipeline. PPM will review the services records to ascertain the constructability of the project, and if services are identified, a load study of these services will be requested.

- **DOT Roadway Stipulations**

Alignment with the DOT roadway stipulations are imperative for a successful full project. Full disclosure of traffic limitations and working hours are required. During this phase of the project the utility will also submit all sketches and drawings of the proposed pipeline segment. These drawings will include but are not limited to Level C surveys, Drawings of valves/regulators and drawings reflecting all dead-ended mains that will be affected by a gas shutdown.

"The reoccurring issue is always corrosion."

• Gas-Lining Layout (GLL)

With all the above information reviewed, PPM will then prepare a "GLL" (gas-lining layout). Our drawing will reflect PPM's industry expertise and will not only layout the excavations needed to recondition the segment but will also include but not be limited to the locations of vent pits, stop-off pits, sleeve locations, the valves needed for stop-off, needed by-pass work and drip-pot considerations. Once complete PPM will request a meeting with your engineers to discuss our layout design. Upon agreement the GLL will be finalized and an estimate outlining the test pit work will be submitted by PPM.

• Purchase Order Procurement

The utility procurement department will review the estimate and will notify PPM to begin initial test pit excavation.

• Test Hole Results

During the test hole phase of the project, PPM will call in the 811 markouts and will be managing an approved subcontractor to dig and sheet excavation as per the utilizes standard. A PPM field supervisor will be on site at all times to ensure safety and to record the data from each pit. The data is then later compiled in a Test Pit Final Report and given to the utilities managing engineer for the project. We will once again conduct a meeting where we explain the data and make changes to the original GLL design if needed. The data collected will also be used at this time for PPM to create a bill of material including the liner material and the respective gas fittings and other miscellaneous gas items.

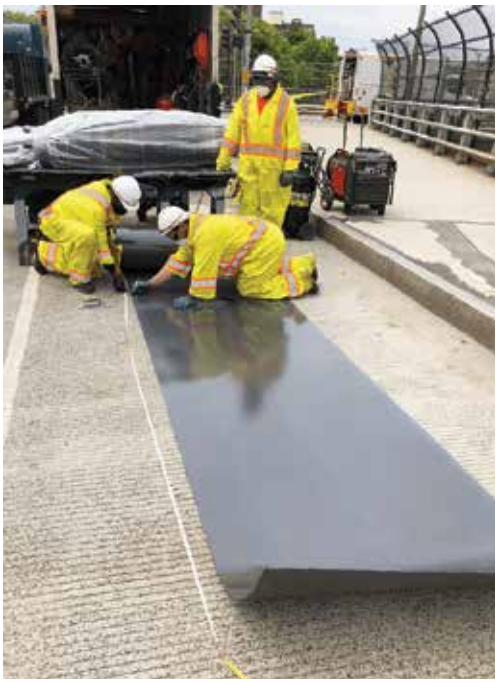
• Full Pit Excavation

Upon PPM receiving the notice to proceed, we will move forward to constructing full sized sheeted excavations. Our skilled subcontractor will have all Operation Qualifications to excavate and perform all needed pipe work to prepare

The PPM Starline 2000 system can line pipelines from 4 to 42 inches

Bridge with pipeline hanging under bridge

Bridge with pipeline alongside



Preparing the Structural Reinforcement Sleeve (SRS) for installation in the bridge abutment

the pipeline for the utility to conduct the gas shutdown. Once shutdown, and the pipeline cut/capped and purged, the pipeline will be then handed back over to PPM so we can proceed with our pre-lining, lining and post-lining procedures.

The CIPL lining process follows the same steps, with the entire process taking just a couple of days. After the sending and receiving pits are excavated, the first step requires a pre-clean CCTV inspection. Robotic cameras confirm the pipeline geometries, check for anomalies and protrusions, and assess the overall internal condition of the host pipe. The next step involves a thorough internal surface preparation using robotic sandblasting and simultaneous recovery of the leftover sand and debris. Adhesive is mixed and prepared and added to the liner. The liner is loaded into the Starline drum, and then inverted and inserted into the pipe. The Starline® liners are a seamless/jointless circular woven fabric-hose made of polyester yarns and a plastic coating (PU/PE) which is bonded as inner liner into the host pipe using a solvent-free two-component adhesive custom fit to each project. After the liner cures, it is cut out on both ends flush with the end of the pipe. The CCTV camera is inserted again to ensure

> *"Leaving the pipeline in place and repairing it using CIPL falls within "grandfathering" guidelines."*

there are no anomalies. The final step is a pressure test and the gas is turned back on. During the entire process, the host pipe remains undisturbed, with no interference at all with neighboring utilities. All the action happens at the excavation points. The complete reconditioning of the entire segment is typically completed within a few days. Curing times vary depending on the ambient temperatures.

As a result, once all segments have been reconditioned our subcontractor will reassemble all of the segments that are considered "dead-pipe" (segments that are not within the same pit as a live gas main), and perform a pressure test to the specifications and standards of the governing utility. Finally, when all pressure tests have passed, PPM will then hand over the pipeline back to the utility to tie-in and reinstate the gas main back to functioning operating order. PPM is also responsible for the backfill & final restoration and installation of paving markers to DOT specification.

BRIDGE REHABILITATION PROGRAM

Currently, we are conducting a Bridge Rehabilitation Program which includes approximately 150 bridges within the Northeast jurisdiction of National Grid.

Repairing and maintenance of a gas pipeline which resides in a bridge or overpass is very different than a repair in a typical roadway buried pipeline. These bridge or overpass repairs are extremely costly as well as logistically difficult and limited to what can actually be allowed by the owners of these crossings, (local municipalities, Rail Roads, etc.)

CIPL liner preparation

The position of some of these gas pipelines place them in a problematic location as they are mostly hung under or alongside the bridge structure, limiting access to the pipeline. In some cases, and the most convenient, the pipeline is resting on top of the structure completely exposed except for where it re-enters the road or offsets into the abutment walls. Most of these bridge or overpass crossings place the pipeline through the abutment wall of the structure, either with a protective sleeve or, in some cases, without the sleeve.

The reoccurring issue is always corrosion, especially where the hangers supporting the pipeline makes contact with the gas carrying pipe. But the greatest corrosion concerns are within the abutment wall itself, where the concrete, combined with water, accelerates the localized corrosion weakening the pipeline at that juncture and in most cases a gas leak is present. Excessive corrosion of the pipeline where the pipe enters the abutment wall of the bridge cannot be repaired without removing the pipe. PPM developed an innovative solution that prevents the need for the removal or excavation of a pipeline. Installing a structural reinforcement sleeve (SRS) has been a choice of gas utilities throughout the industry for this purpose. The carbon fiber SRS reinforces the corroded pipe with a carbon fiber sleeve without the need to remove the pipe.

The SRS has been tested at pressures to 250 PSI and approved by the Gas Technology Institute for its strength, durability and compatibility with PPM's Starline CIPL product. This innovative approach is accomplished by installing a Carbon Fiber sleeve into the gas carrying pipeline directly

Readying a 42-inch gas main for liner inversion

at the bridge abutment wall. PPM's SRS sleeves are made of a high strength carbon fiber laminate with a glass outer skin, and are installed robotically into the pipeline. The laminate composite material and glass outer coating prevent corrosion. The carbon fiber material bonds to the interior of the pipeline, and improves the pipe's integrity at the position of the installation. While each project is unique, carbon fiber SRS can save utilities as much as $500,000 per project by preventing future corrosion and eliminating the need for costly additional excavations and pipe work.

The local municipalities or owners of the bridge will not allow the replacement of the pipeline, especially where it enters and exits the abutment wall of the bridge structure. Re-engineering pipe supports and hangers or attempting to remove the old corroded pipe from the abutment wall is cost prohibited and, in most cases, not allowed by the municipalities.

The solution is to simply recondition the pipeline using Cured-in-Place lining (Starline-2000) and reinforce the pipeline within the abutment wall without disturbing the pipeline or the structure of the bridge. This is done very simply by beginning and ending the Cured-in-Place Lining process outside or beyond the limits of the bridge. The first step is to review the drawings of where the pipe connects to the road. The process is done using two excavation points at the beginning and ending points where the liner is inserted. These excavation pits are done outside or beyond the limits of the bridge. We cut and cap the main and line it from these two points. Leaving the pipeline in place and repairing it using CIPL falls within "grandfathering" guidelines, thus avoiding the need for total replacement. CIPL is far less expensive than replacement, and in most cases is the only viable option.

The complete reconditioning of the entire segment plus the reinforcement of the pipeline at the abutment wall is typically completed within a few days (plus the curing time based on ambient temperatures). The reconditioning will add an additional 100 years of reliable life to the old existing pipeline including the reinforcement of the pipeline at the abutment walls. This entire process did not disturb the pipeline, it did not affect the hangers that support the pipeline nor did it disturb the pipeline within the abutment wall, making CIPL a perfect solution to an expensive, and most of the time, unable to repair within a bridge pipeline.

ABOUT THE AUTHOR:

Claudia Law, *Vice President of Construction at PPM, is a skilled construction professional and industry expert in pipeline rehabilitation. She currently sits on the Board of Directors of the North American Society for Trenchless Technology-Northeast Chapter. Before joining the PPM Family in 2017, her career included the development and construction of several mid-rise luxury buildings in the NY metropolitan area totaling $355 million. She has a strong background in sustainable infrastructure and project management. Since becoming an integral part of PPM, Claudia has successfully led the rehabilitation of approximately 35,000 feet of high pressure/large diameter natural gas pipelines in the northeast region of the United States.*

INNOVATIVE TECHNOLOGY BENEFITS

The PPM Starline 2000 system can line pipelines from 4 to 42 inches with a MAOP to 180 PSI. Our technology has also been independently tested by NYSEARCH/PHMSA and Cornell University. The case study determined a 100 + year viability of field-aged Cured-in-Place pipe as alternative to full pipeline replacement. The tests also determined that CIPL provides substantial pipeline renewal and is a viable option to conventional replacement methods for cast-iron and steel distribution pipelines. Our product meets ASTF 2207-02 and 2207-06. Due to further advancements in our operating procedures and equipment, PPM now has the capability to line segments up to 1,300 feet with only two excavations.

One of PPM's most innovative trenchless techniques is the use of using Carbon Fiber Structural Reinforcement Sleeves (SRS) to secure the integrity of damaged pipelines. High strength carbon fiber material in the form of a "sleeve" is inserted robotically into the pipeline. Carbon fiber is light, with high-tensile strength, high temperature tolerance, and low thermal expansion, properties which make carbon fiber ideal in diverse applications, from aerospace and engineering, to motorsports and sailing.

PPM's robotic devices and method of installing carbon fiber sleeves, have been part of our ongoing effort to improve the efficiency of CIPL. The proprietary process was developed in 2011 and is used effectively to reinforce bridge abutments, reinforce corroded high-pressure gas mains, and to span gaps in pipelines (for example, where drip pot standpipes must be removed). PPM can design, develop and test custom robotics to install carbon fiber sleeves in pipelines safely and effectively. Robotics with extendable reach features can cut away the existing drip standpipes, allowing the carbon fiber sleeve to create a "bridge" across the drip cavity. The carbon fiber bridge allows for seamless lining without incurring costs for unnecessary and costly excavations.

Case Study: Leveraging a Proven Approach to Staffing that Elevates Safety, Quality and Environmental Culture

Culture Elevation with the Joe Knows Energy High Performance Program

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

PROVEN PERFORMANCE MODELS TO SOLVE A MAJOR INDUSTRY CHALLENGE

Throughout our industry, leaders are concerned with improving capabilities within teams. From hiring the right inspectors and contractors to managing reporting and safety requirements, top performing companies are seeking new ways to manage growth, achieve scale, and maintain compliance and reporting requirements.

The previous several years have been a challenge with companies facing a host of issues including increased regulatory oversight, new requirements for verifiable field records, and increasing demand and competition for field talent.

Our team has been committed to helping companies improve safety, quality, and environmental culture with programs focused on recruiting, retaining, and training high-performance field team members. In the last few years, we've conducted multiple pilot programs to test the effectiveness of these programs, define new best practices, and document the results of the programs.

CHALLENGE: RAPIDLY SCALING FIELD WORKFORCE WITHOUT SACRIFICING PERFORMANCE

The Customer

Our client is a natural gas and utility provider serving greater than 1.6 million customers. The company needed to **increase their inspector workforce quickly and effectively**. As they were adding significant numbers of inspectors, they needed better tools and resources to select candidates that could meet their standards for expertise, safety, and culture fit.

The Solution

Our team worked with the company's leadership team to define standards, create a culture fit analysis, and determine joint key performance indicators. We **recruited and screened more than 2,000 applicants**, narrowing the final candidate pool to 25 highly qualified candidates. After final review, **five new inspectors were hired** including a Team Leader to lead, coach, and manage the inspectors.

The intent of our pilot program with the client was to determine if our High-Performance Program could produce candidates who would meet the standards and be capable of full-time employment.

The Results

After several months of our pilot, we've continued to place inspectors, expand the program, and gather feedback. The program has **proven successful based on our initial planned performance goals**. Some of the results include:

- 100% Retention
- Inspectors Transitioning to Employment
- Expanding the Scope of the Pilot Program
- Impact of Team Leader Proven Successful

"JKE provides value… with resources, processes and tools to recruit, assess and select candidates that have the right mindset and experience to elevate the team."

-Director of Construction

CHALLENGE: IMPROVING PERFORMANCE IN EXISTING TEAM FOR MID-SIZE GAS UTILITY COMPANY

The Customer

The client is a natural gas and utility provider serving 80,000 clients in the Northeast US. The company is halfway into a 10- year pipeline replacement program. They were working with six vendors providing third-party inspectors including JKE and **wanted to improve and standardize their recordkeeping**. With twenty third-party inspectors working across six different service providers, this was a challenge.

As they worked to improve their records, they needed a way of improving inspector performance without assuming the employment liability of an internal employee.

The Solution

Our team developed a standardized Team Leader manager framework that created a working manager role allowing a senior inspector to spend time ensuring quality and timeliness of records, managing staff members, coaching the team for performance, and supporting soft-skills training on the job.

In addition to the team leader role, we developed onboarding and training resources to accelerate the learning of company standards and implemented a process of continuous improvement.

The Results

After a year of this program, the client has improved recordkeeping program and Team Leaders ensure the correct information Is provided completely within the required time frame. **This has led to better regulatory audit results** as well as:

- Substantial Improvement in Quality, Completeness, and Timeliness of Information
- Standardize Team Leader and Onboarding Model Used with All Vendors

"The success of the High-Performance Program is due to Joe Knows' commitment to onboarding and training. They are always looking to improve processes through continuous feedback, communication, and by investigating new, innovative technology."

-Director of Gas Compliance

CHALLENGE: BUILDING A NEW, HIGH-PERFORMING TEAM FOR A MID-SIZE GAS MIDSTREAM COMPANY

The Customer

The customer is a mid-size natural gas midstream company with over 200

miles of water service lines serving production wells in the Northeast US. The company noticed a reduction in talent and training of water transfer vendors after a slow period in the market. They began **looking for ways to improve the quality of service** provided by subcontractors after seeing **significant increases in issues related to safety performance, environmental protection, and cost.**

The Solution

We wanted to help this company create a team of third-party consultants who could deliver the results and live the culture. Our team collaborated with their leadership to develop standard benchmarks for high-performance in the role(s).

This benchmark strategy and culture fit method was used to recruit and retain new team members. We implemented a Team Leader strategy and sought leaders that could coach and inspire others to achieve better performance over time.

The Results

Over the course of two and a half years, the results in safety performance, environmental protection and cost have been substantial. Results include:

- 83% Retention
- 66% Reduction in Safety Incidents
- 50% Reduction in Environmental Incidents
- Within 0.5% of Budget Versus 30% Over in Previous Periods

> *"JKE is changing the industry, by providing inspection professionals who fit the culture, are accountable, and integrated with the team."*
>
> *-Director of Capital Construction*

KEYS TO IMPLEMENTING STRATEGIES IN YOUR COMPANY'S CULTURE ELEVATION STRATEGY

Focus on People First

We know that culture is first and foremost, about people. Our High-Performance Program looks at various data in the hiring process to recruit and retain candidates that have the right technical and soft skills, behavioral fit, and culture fit for defined performance standards.

Boots on the Ground Team Leaders

Team Leaders proved to be an essential part of our performance in every case. Having an experienced field manager who is active on the job site, engaged with the team daily, and supporting regular coaching and development efforts.

Clearly Define Your Standards

Define the standards you're looking for in hiring, retention, development, and culture fit. The more clarity you gain around this, the more you can reduce turnover and increase performance of new hires in critical roles.

Strategic Relationships Require Consistency

Every third-party resource you work with for inspection should schedule consistent performance reviews, feedback sessions, and KPI reviews to adjust and adapt strategy as you go. These strategic reviews and performance strategies are an important aspect of our success in our pilot programs.

NEXT STEPS

Are you ready to elevate your safety, quality, and environmental culture? Are you looking for ways to improve reporting performance or increase new hire performance?

Reach out to our team at Joe Knows Energy or visit www.JoeKnowsEnergy.com for a free workshop and consultation. Our team will help you begin the process of defining your needs, understanding performance management, and determining how our High-Performance Program might work in your organization.

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.

START IMPROVING YOUR SAFETY, QUALITY AND ENVIRONMENTAL CULTURE NOW

YOU CAN RELY ON OUR TEAM FOR HELP WITH:

01 Rapid Scaling of Inspector and Field Workforce

02 Improving Performance of Existing Teams

03 Building a New, High Performing Team

04 Implementation of Performance Strategy

> *JKE provides resources, processes and tools to recruit, assess and select candidates that have the right mindset to elevate the team.*
>
> -Director of Construction

HOW WE CAN HELP

Our team has been committed to helping companies improve safety, quality, and environmental culture with programs focused on recruiting, retaining, and training high-performance inspection and frontline team members.

How can we help you improve your company culture?

LEARN MORE

Scan the code with your smartphone or view our case studies online at JoeKnowsEnergy.com/EvidenceofSuccess

Contact:

614-989-2228 OR
Dan@joeknowsenergy.com

JOE KNOWS™

TALENT | TECHNOLOGY | SOLUTIONS

Weak Link Good Practices

For trenchless pipeline installation projects, the use of weak links is important to ensure that plastic gas pipe allowable tensile stress is not exceeded during the process of pulling the pipe through the ground. All weak link methods or devices should be designed to fail at or before the plastic pipe allowable tensile stress.

Providing utilities with information about acceptable types of weak links and good practices will ensure that they are utilizing the appropriate method or device on the Allowable Tensile Load (ATL) for each standard size of plastic pipe or tubing.

With sponsorship from Operations Technology Development (OTD), GTI reviewed the industry's best practices, evaluated various commercially available equipment for trenchless installation of plastic pipe, and developed a Weak Link Break-away Good Practice Guide for OTD members.

The project team connected with subject matter experts for the project, and Dr. Mark Knight from eTrenchless Group, who is an Associate Professor in the Department of Civil and Environmental Engineering at the University of Waterloo, as well as the Executive Director for the Centre for Advancement of Trenchless Technologies (CATT), was chosen to lead development of the guide. A survey of OTD members and contractors to evaluate the current state of the industry provided insight on procedures, commercially available weak links, "homemade" weak links, and industry best practices to serve as the basis for the guidance document.

While the new federal directive specifies and enforces the use of weak links to avoid pipe damage during installation, there are currently not any methods to ascertain that the installed pipe is not over stressed. In response, GTI recently launched the development of a load measurement device and data logging system to monitor the pull load at any given time during the pipeline installation. In addition, an Allowable Pull Load Calculator website application is being developed to provide an easily accessible resource for field personnel.

gti®

OTD Operations Technology Development

For more information contact:
Dennis Jarnecke, GTI R&D Director, Energy Delivery
847-768-0943 | djarnecke@gti.energy

NASTT's GOOD PRACTICES TRAINING COURSES Earn CEUs

Join us for a

NASTT NORTHEAST REGIONAL CHAPTER

FREE Introductory Webinar on Trenchless Good Practices for the Gas Industry!

DATE: WEDNESDAY, JULY 13
TIME: 11:00 AM – 12:00 PM ET
LOCATION: YOUR COMPUTER!

This introductory webinar is open to gas utilities that are interested in a preview of the full length NASTT's Gas Distribution Good Practices Course. Presented by industry expert volunteers George Ragula of RagulaTech and NASTT Board Chair Alan Goodman of HammerHead Trenchless.

Then join us again for NASTT's Gas Distribution Good Practices Course!

DATE: WEDNESDAY, SEPTEMBER 21
TIME: 11:00 AM – 3:00 PM ET

The course is based on several North American Society for Trenchless Technology (NASTT) Good Practices Guideline Manuals – a series of industry-developed documents that provide contractors, engineers and owners with a set of guidelines to assist in successful trenchless installations and operations. Who Should Attend? The target audience includes utility engineers, utility operations personnel, designers, managers and individuals involved with the construction, rehabilitation and management of underground utilities.

Contact NASTT Education Specialist Kari Schiffner at kschiffner@nastt.org with any questions.

Visit www.nastt.org/training/events for registration links

DOE-ARPA(E) REPAIR PROGRAM UPDATE:

First Year Perspective and What's Next

By: Jack Lewnard, DOE – ARPA(E)

DOE's Advanced Research Projects Agency – Energy was established in 2009 to explore high-impact technologies that are too risky for the private sector. REPAIR (Rapid Encapsulation of Pipelines Avoiding Intensive Replacement) is a 3-year, $38 million program with ambitious goals for natural gas distribution pipes. The program seeks new technologies to rehabilitate the pipes, extending their life by 50 years, with minimal surface disruption while the pipes are live, and with a cost less than $1 million per mile. Seven teams are developing robots that can provide polymer or metal coatings on the inside of the pipes, and then run inspection tools to verify the coating integrity. As part of this effort, we are developing the test procedures and hardware to confirm pipe life, and mapping tools that can create 3-D images of the pipes and adjacent buried infrastructure. The following table summarizes the teams and their areas of focus. While the program targets gas distribution pipes, we anticipate the technologies will find initial markets in water and sewer lines as well.

We've just completed the first year and would like to share progress on the REPAIR initiative. The teams have tested many coating materials. Metal coatings were expected to be very challenging, starting with the cost of materials. As discussed below, it appears metals may be best suited for local repairs (welds, pits, etc.) vs. coating the entire internal length of the pipe. The metal coatings teams are actively seeking information on potential applications. On the polymer side, the teams have identified a diverse set of formulations, with and without fiber reinforcement. There's still much work to be done with the coating deposition and integrity inspection robots, but initial prototypes show a path to success. The testing team has identified the major failure mechanisms and developed test procedures and is building the testing rigs. This information is available to any company interested in developing coating technologies. Finally, the two mapping teams are making very good progress. The precision of mapping from the surface is meeting or near to the +/-10 cm target in X,Y, and Z. Mapping tools for inside the pipe, mounted on commercial inspection tools, can "see" and quantify defects with unprecedented resolution.

> *"The program seeks new technologies to rehabilitate live gas pipe, extending life by 50 years, with minimal surface disruption."*

While there's still a lot of work ahead, the teams have a great start. Each project team has provided a brief status report below. We are interested in hearing from stakeholders – pipe operators, inspection companies, contractors, and regulators. Your input is critical for guiding the technical and commercial development of the REPAIR program. You can meet the teams at the 2022 ARPA-E Energy Innovation Summit May 23-25 in Denver, Colorado. Please send questions or feedback to me at jack.lewnard@hq.doe.gov. For more information, refer to the REPAIR Annual Meeting presentations at https://arpa-e.energy.gov/2022-repair-annual-meeting.

Technical Approach	Team Lead
Testing and Analysis of Pipeline Encapsulation Technologies	**University of Colorado Boulder**
Metal Spray-Based Rehabilitation	**University of Maryland** **ULC Technologies** **University of Pittsburgh**
Polymer-Based Rehabilitation	**General Electric Global Research** **Autonomic Materials** **University of Delaware Center for Composite Materials** **Oak Ridge National Laboratory**
Pipe Locating	**White River Technologies** **Carnegie Mellon University**

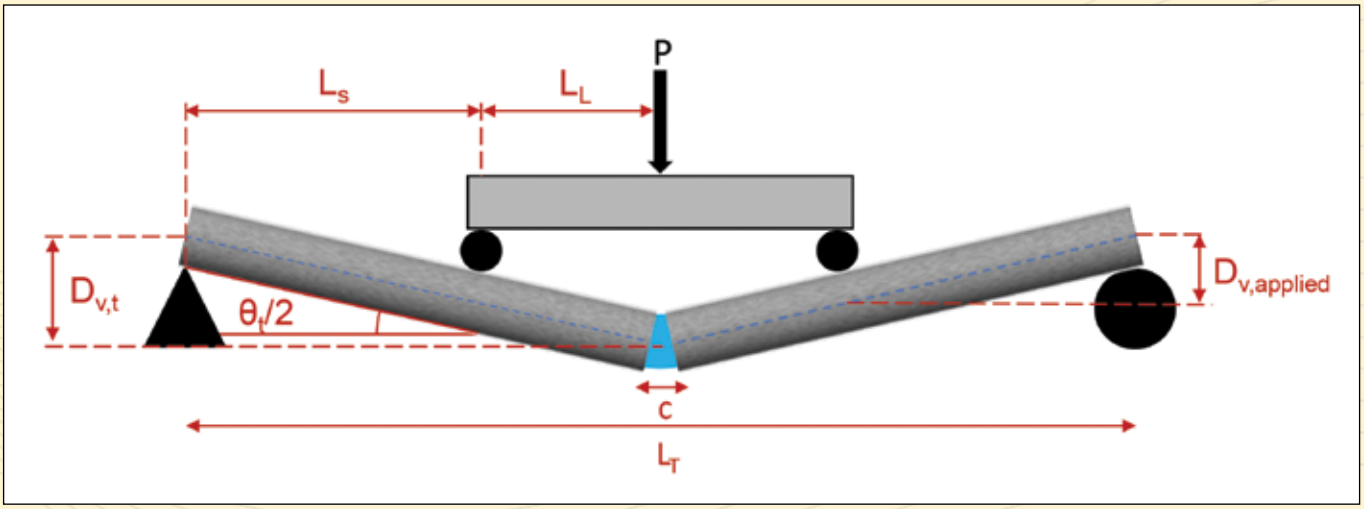
REPAIR 2022 Program Updates

TESTING AND ANALYSIS OF PIPELINE ENCAPSULATION TECHNOLOGIES

University of Colorado, Boulder

As the Testing and Analysis (T&A) team, the University of Colorado Boulder (CUB)-led team, consisting of the University of Southern Queensland (USQ) and Gas Technology Institute (GTI), will validate a 50-year design life for innovative pipe-in-pipe (PIP) systems by developing numerical, analytical, and physical testing protocols. The T&A team's framework characterizes performance objectives and establishes performance criteria to support recommendations for PIP material properties. Testing pipes lined with materials already known to industry informs the initial framework. Steel and cast-iron pipe samples lined with Sanexen's ALTRA10TM (an American Water Works Association (AWWA) Class IV bonded liner used in the water industry) are undergoing lateral load testing at the CUB's Center for Infrastructure, Energy, and Space Testing (CIEST) lab. The lateral load tests simulate parallel trench construction and overhead traffic loading. To simulate seasonal temperature changes, the pipes will also be subjected to axial loading tests. The experimental results from the lateral and axial testing will be compared against the University of Southern Queensland's 3D finite element models for further model calibration. These Ansys- and Abaqus- based models will help REPAIR research performers cost-effectively evaluate scenarios and impose deformations reflecting expected field conditions on their lab specimens. USQ's modeling of host pipe edge effects and length scales will also assist GTI's internal pressure testing of the internal REPAIR pipe. The T&A team is looking forward to receiving and testing samples from the other REPAIR teams and will make its reports, test protocols, and software tools publicly available. For more information, please contact Prof. Brad Wham and Morgan Ulrich: Brad.Wham@colorado.edu and Morgan.Ulrich@colorado.edu.

12-inch steel pipe lined with ALTRA10TM undergoing lateral load testing



Schematic of pipe subjected to 4-point-bending test simulating approximately 500,000 cycles of traffic loading

METAL SPRAY-BASED REHABILITATION

University of Maryland

The University of Maryland team has developed a comprehensive solution for performing in-situ structural repairs on steel, cast iron, and other metal piping and pipelines. Based on an integrated (experimental and computational) approach, a slurry-based coating and patented high-temperature sintering process builds new metal in a pipe-in-pipe configuration. This can be used in either a complete pipe-in-pipe embodiment or for patch repairs.

The sintered steel layer features a 0.08-0.2inch (2–5 mm) thickness per layer, a density of >90 percent, high hardness (>100 percent of the original pipe material), and good strength (>50 percent of the original pipe material). A gradient structure design for heat management and thermal modeling frameworks to closely control the temperature and energy distribution overcome the challenges of elevated temperature on the pipe outer surface, particularly in the presence of plastic service connection fittings.

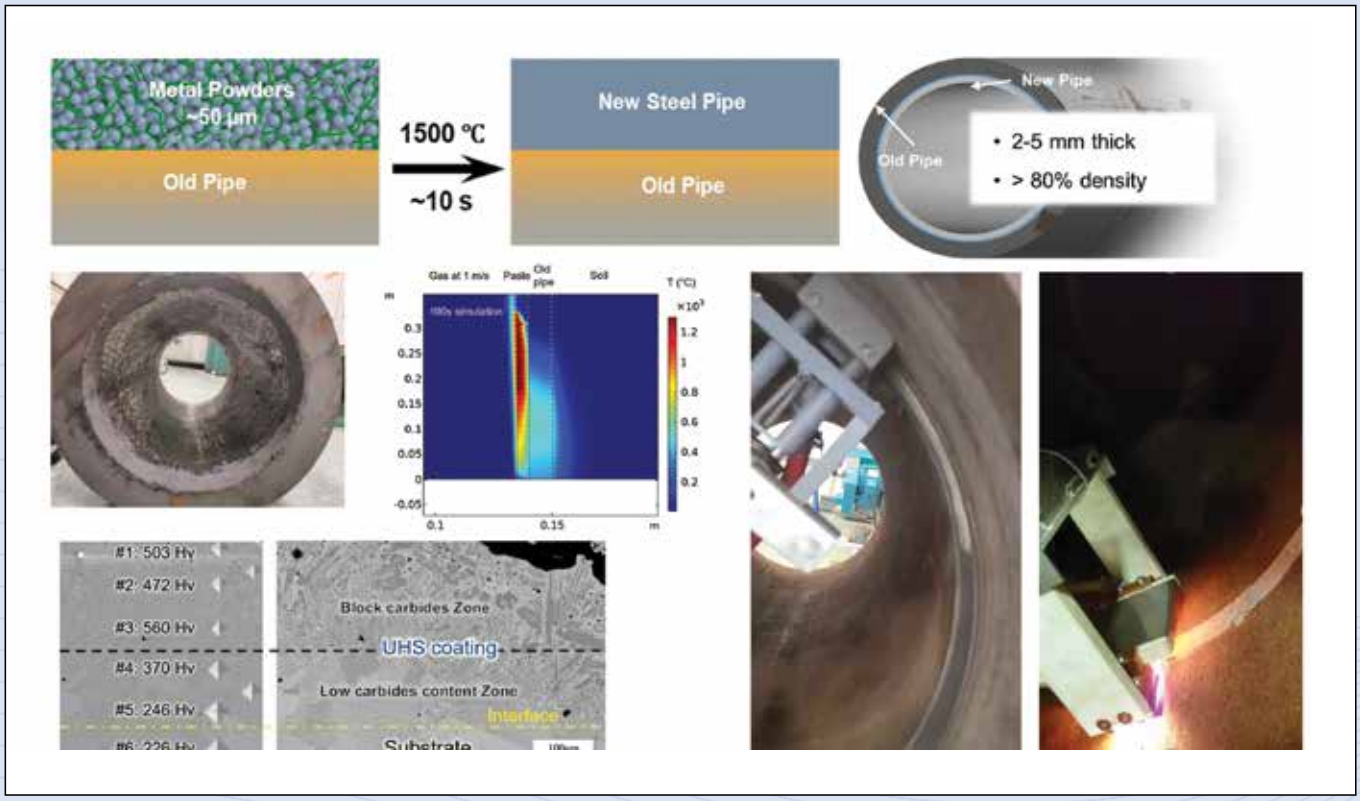
The developed approach can be used to renew legacy piping in applications including natural gas, petroleum, steam, and other liquids. The approach can also be used to prepare existing piping for reliable hydrogen service. The sintered metal material has good adhesion to the original pipe as well as excellent mechanical properties. Utilities and pipeline operators have shown interest in this technology, and we are open to working with utilities, contractors, and other entities as we move into commercialization with pilots and other planned projects. For more information, please contact Dr. Liangbing Hu: binghu@umd.edu.

ULC Technologies

ULC Technologies (ULC) and the Penn State University Cold Spray Lab are developing a novel approach for rehabilitating live natural gas distribution pipelines using Cold Spray Additive Manufacturing (CSAM). Robotic inline fabrication of a new pipe will be performed inside a natural gas main without disrupting customers. Materials sprayed can be structural, such as stainless steel or custom-developed alloys that offer corrosion protection, high-temperature operation, and high-pressure hydrogen damage resistance.

Stainless steel coatings sprayed and tested in the lab showed excellent strength, ductility, and porosity values. ULC initially sought to use methane as the process gas for compatibility with the host pipe, but after evaluating field and lab challenges, nitrogen was deemed to be more suitable. The robot will employ a recovery system to remove undeposited metallic powder and nitrogen during fabrication to prevent dilution and contamination of the natural gas. Early robotic concepts have been developed that indicate technical feasibility.

While the technology development originally targeted natural gas distribution mains, early market research shows a broader need. Spot repairs performed in natural gas transmission mains may be a more economical approach for reinforcing



(A) University of Maryland pipe-in-pipe approach for metal powder printing and ultrafast, high-temperature sintering. (B) Printed metal powder pasted on the inner surface of a cast iron pipe. (C) The developed thermal model to guide the sintering process. (D) Sintered SS316 layer has high hardness, good mechanical strength, and excellent density. (E) Our robotic continuous printing system. (F) Our robotic continuous sintering system

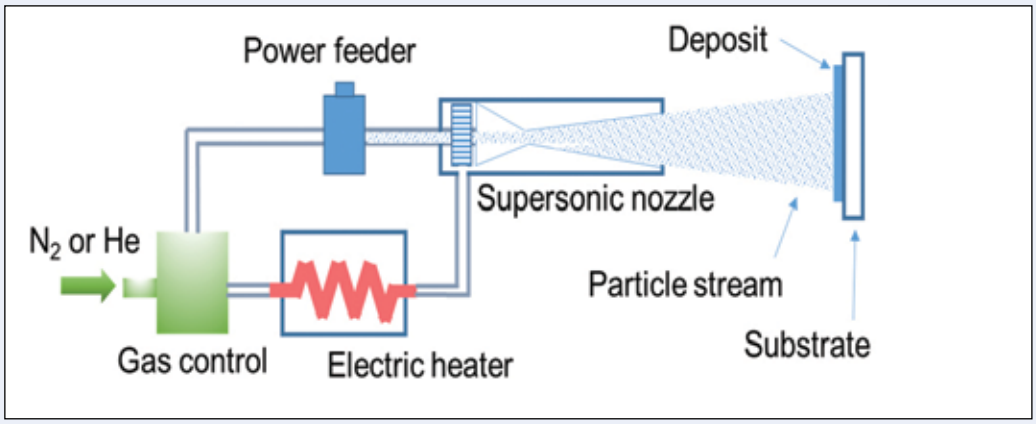
distribution and transmission mains compared with full pipe-in-pipe rehabilitation. Additive manufacturing offers custom programming, high accuracy, and precision. This means custom contours can be manufactured in situ, offering flexibility in the repair solution such as filling corrosion pits or fabricating internal full-circumferential sleeves. The value of the repair can be high at difficult-to-reach locations and in pipes that need reinforcement before injection of methane-hydrogen blends. Other relevant markets include district heating pipelines and critical pressurized water and wastewater assets. ULC is interested in partnering with the industry seeking to deploy the robotic CSAM technology for rehabilitation applications and welcomes any inquiries please contact Mr. Aalap Shah; aalap.shah@spx.com.

University of Pittsburgh

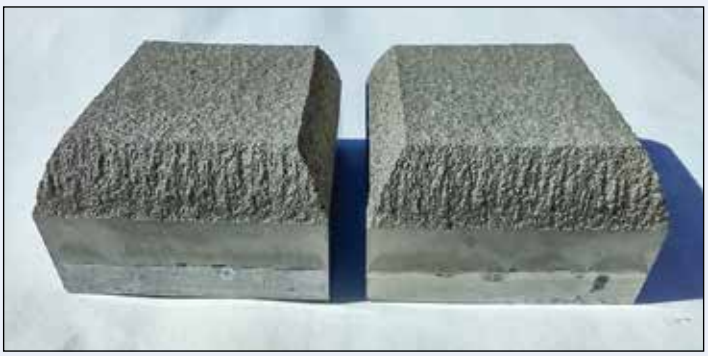
The University of Pittsburgh team is developing a robotic fiber optic deployment tool and distributed fiber sensors with ultrasonic guided acoustic wave interrogation techniques for real-time pipeline health inspection and, in collaboration with Pacific Northwest National Laboratory, metallic cold-spray based in-pipe rehabilitation technology. The low-cost and high-performance distributed fiber optic acoustic sensors being developed by the University of Pittsburgh's Ohodnicki Lab can monitor pipeline integrity by measuring leak detection, third-party intrusion, temperature distribution, and excessive strain over tens of kilometers. In contrast with existing externally deployed commercial fiber optic sensors with their limited retrofit capability and information provided, the team has developed a patented robotic internal deployment approach with BrainDrip, LLC, that uses a self-contained semi-autonomous device to propel, install, and embed a fiber optic cable in a range of pipe diameters. Successful deployment of fiber optics using the tool has been demonstrated for 8-inch outside diameter and 50-foot long pipe. See demonstration videos: https://drive.google.com/file/d/1KnItgxANdp-4Ja33TK_dT2V1vHlA6zTZ/view.

High-quality cold-spray metallic coating deposition of sufficient thickness for pipe-in-pipe repair on pipeline steels has been demonstrated. Additional key technical challenges being addressed include an (1) in-pipe cold-spray demonstration within a pipe of diameter 8-12 inches and (2) techno-economic analysis and deployment scenario scoping to prioritize future technology development. For more information, please contact Prof. Paul Ohodnicki: pro8@pitt.edu.

Current version of the fiber optic deployment tool (FODT) entering an 8-inch pipe during a 50-foot demonstration of fiber optic sensor installation along pipe interior



Cold-spray technology successfully used to deposit >5mm thicknesses of structural steel alloys on a pipeline steel substrate (b), estimated to be sufficient in thickness for a pipe-in-pipe repair technology



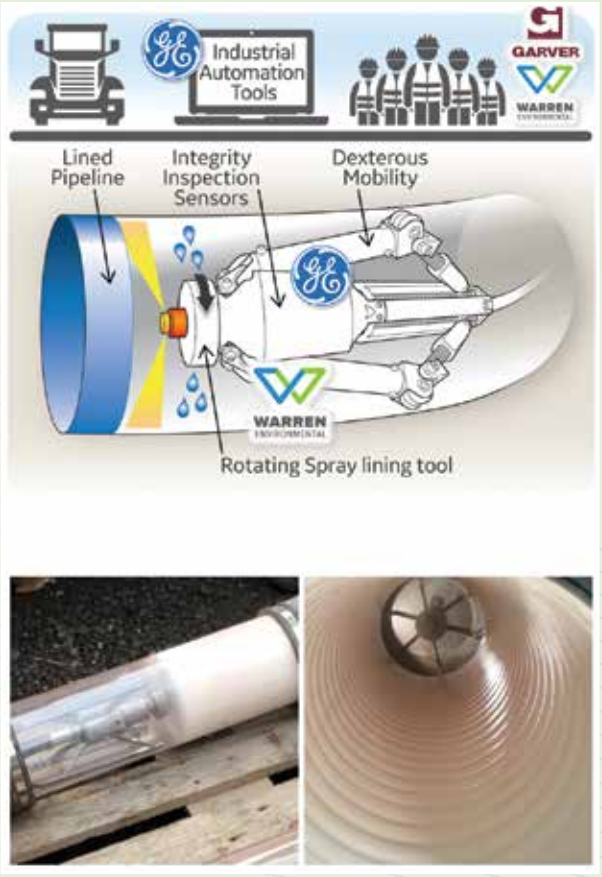
POLYMER-BASED REHABILITATION

General Electric Global Research

Over the past year, GE Research, Warren Environmental, and Garver, LLC, have made substantial progress on discrete system components that will be integrated into their PipeLine Underground Trenchless Overhaul (PLUTO) system – a long-distance minimally invasive pipe repair system, including:

1. Spray-on coating system material properties validation to predict life-cycle characteristics
2. Selective surface preparation approach evaluation to ensure a close bond where necessary (to seal interfaces) while allowing structural independence elsewhere
3. High-pull capacity robotic delivery system prototype validation
4. Pre-and-post coating inspection technology evaluation to enable advance detection of issues that may prevent a successful coating as well as detecting residual life-limiting defects post-coating

With accelerating PLUTO system technical development, a field demonstration is anticipated in late 2023. In parallel, the PLUTO team is exploring applicability to adjacent domains including water and wastewater. Pipeline owners and regulatory agencies are being engaged early in the development process to promote pipe rehabilitation system acceptance. 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. For more information, please contact Todd Danko: todd.danko@ge.com.



The PLUTO system tightly integrates industry leading capabilities in robotic mobility, asset inspection and pipe lining material application

Autonomic Materials

As a solution for the escalating costs associated with rehabilitating legacy pipe, Autonomic Materials, Inc., (AMI) and its partners are developing ExiPiPTM, a robotic trenchless system providing an extruded-in-place, structurally independent pipe offering self-healing and self-reporting functionalities.

Since the REPAIR program began during late 2020, the AMI-led team has achieved notable progress despite Covid restrictions and supply chain challenges. Several key milestones reached during this initial year helped move the ExiPiPTM solution from conceptual design to production of initial pipe samples. Using a novel frontally cured poly-(dicyclopentadiene) (DCPD) for the pipe material, the AMI team demonstrated how a DCPD resin formulation could be converted from a liquid gel to a cured pipe with minimal heat energy in a matter of seconds. Other technical highlights included successful efforts toward refining self-healing capabilities using poly-(DCPD) and embedded self-reporting mechanisms created to assist with future inspections.

Much of the team's early work focused on optimizing the DCPD resin formulation rheology to minimize sag and facilitate extrusion. The AMI team's extensive R&D resulted in a formulation that remains a transportable liquid until extruded while still producing polymerization on demand in conditions likely to be encountered during field operations. Projected costs and performance criteria have remained on target, meeting the goal of delivering a replacement pipe solution at a cost of under $1 million per mile. Although originally developed to meet the needs of gas distribution line repair, ExiPiPTM is proving attractive in other applications demanding a permanent, structurally independent pipeline repair solution enabled by a modular robotic platform with a suite of inspection and characterization technologies. To learn more, please contact Gerald Wilson: gw@autonomicmaterials.com.

University of Delaware Center for Composite Materials

The University of Delaware – Center for Composite Materials (UD-CCM) and Plitzie Inc., are developing a novel composite placement and inspection process to fabricate stand-alone structural pipe within existing legacy pipelines—with no disruption in gas service. The internal Wound Rapid Automated Placement (iWrap) process uses low-cost, UV-curable, glass fiber reinforced plastics (GFRP) for discrete preforms made from continuous and aligned short fibers. These sections will be transported and placed within the pipe to meet a 50-year service life; address the unique pipe repair loading conditions; and enable preform design customization to accommodate the pipe's corrosion, access points, or other local features.

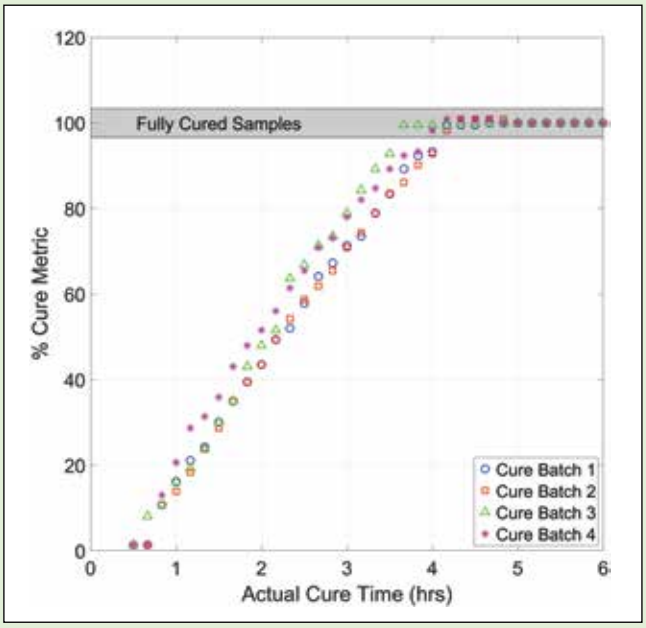
The iWrap approach offers maximum design flexibility and minimizes installation time and cost. Custom sections can allow for lateral tees, service connections, joints, irregular cross sections, and increased thickness to meet high external loads under railroads and highways

or where soil erosion and movement occur. A multi-functional carbon nanotube-based multi-layer sensor array embedded within the composite iWrap pipe provides structural health and leak monitoring. Machine readable data is printed on the individual pipe interior wall segments for production QA/QC as well as geo-tagging location information for future servicing requirements.

In addition to enabling custom sections, the highly conformable TuFF (Tailorable universal Feedstock for Forming) material with its high-fiber volume fraction (>50 percent) offers affordability while exhibiting significantly higher strength and stiffness than standard neat resin pipe material. Minimizing wall thickness and required material volume reduces material cost, minimizes transport time inside the pipe, and allows rapid UV-cure of sections. Estimated total placement costs are well below the FOA target of $1M per mile repaired/replaced. iWrap threshold target speed in straight 12-inch pipe sections is ~4m/hr including the placement/consolidation/UV-cure steps. To learn more, please contact Dirk Heider: heider@udel.edu.

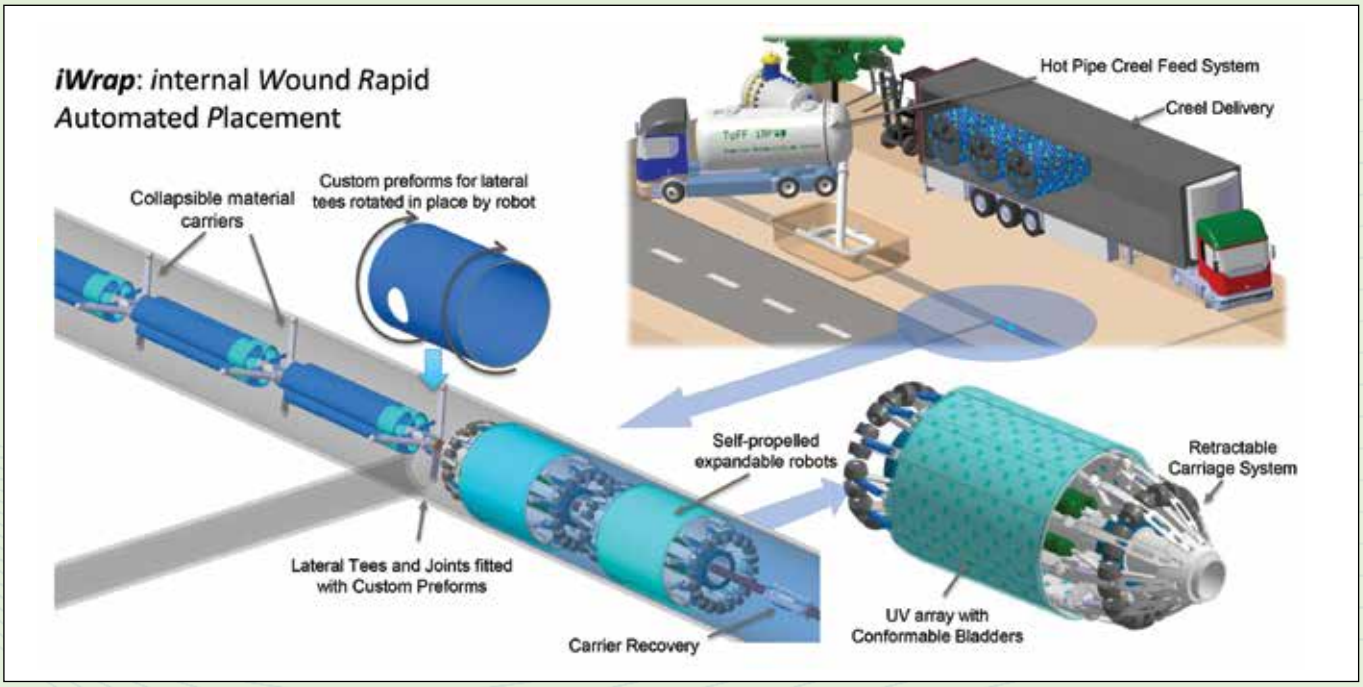
Oak Ridge National Laboratory

Oak Ridge National Laboratory, in partnership with Diakont, the University of Tennessee-Knoxville, and LifeLast, is using a combination of new structural polymer composites, innovative pipe-in-pipe deposition methods, and new inspection tools to develop an integrated, complete robotic rehabilitation system for in-situ structural pipe renewal. During the past year, the team developed new resin formulations with >50 MPa (7.25 KSI) tensile strength. Specially engineered pipe-in-pipe deposition systems have been developed with proof of concept demonstrated in short pipe sections. Diakont has developed a robotically deployed, automated laser scanning technology that assesses pipe conditions in preparation for the pipe-in-pipe installation. Additionally, a new



Oak Ridge National Laboratory In-situ monitoring of epoxy curing by LIF

Laser Induced Fluorescence nondestructive examination system for post-inspection has been successfully designed and commissioned for monitoring epoxy cure processes, including chemical composition differences and the epoxy mixture cure state. Based on our current material formulations and assumptions, the "no-dig" rehabilitation cost for a 12-inch diameter gas distribution piping section using this material and system meets the program goal of approximately $1 million per mile. During 2022, the team will be scaling up the deployment tooling toward validating pipe-in-pipe deposition demonstration and testing. To learn more, please contact Tomonori Saito: saitot@ornl.gov.



The University of Delaware Center for Composite Materials iWrap approach employs a self-propelled, dual-inflation expandable bladder system that places, consolidates, and cures standard or custom composite sections along the entire pipe length in a continuous co-cure process

PIPE LOCATING

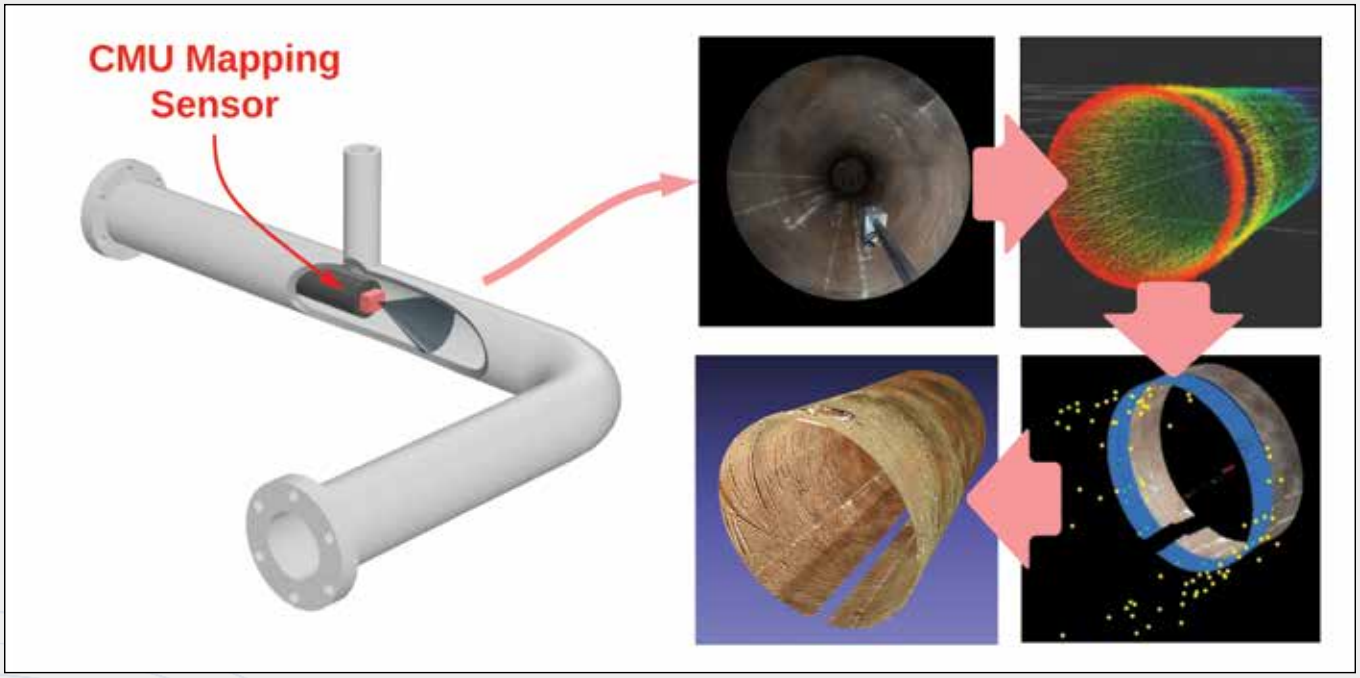
Carnegie Mellon University

The Robotics Institute at Carnegie Mellon University (CMU) is developing an advanced in-pipe localization and mapping sensor system that can be installed onto virtually any mobile robot dedicated to pipe inspection and repairs. The first-generation proof of concept system can create pipe inner surface 3D scans at 0.72mm resolution and achieve accurate localization with no more than 0.86 percent relative drift rate. This sensor technology can perform computation on the edge to significantly reduce integration time and cost, while providing value added inspection service with cutting-edge artificial intelligence.

Easy-to-integrate tools will allow for rapid deployment of next-generation inspection and service machinery into pipes, expediting timelines and reducing repair costs. A mobile robot moving through the pipes collecting sensory data and effecting repairs will need to integrate sensory signals (LIDAR, ultrasound, eddy current, imaging, etc.) with advanced mobility systems to create in-pipe maps. These maps will allow field technicians and applications engineers to geospatially locate items of interest, such as anomalies, leaks, wall thickness, and coating deposition test results. The maps will also support targeted maintenance identification and diagnostics by enabling precise navigation to localized concern areas in the broader pipe network. Currently the CMU project is actively looking for both sensor prototype beta testers and commercial partners. To learn more, please contact: biorobotics@andrew.cmu.edu

White River Technologies

White River Technologies, Inc. (WRT) is developing an advanced 3D electromagnetic mapping technology for subsurface pipe



CMU in-pipe mapping sensor concept (left) with example pipe inner surface scan and point cloud reconstruction result (right).

APEX pushcart ships compactly and quickly assembles in the field

APEX surface pushcart detects, locates, and classifies underground pipes

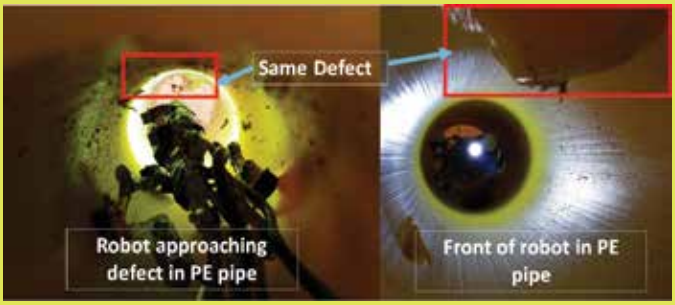
detection, location, and characterization. This project leverages APEX, WRT's core technology used for precise detection and identification of buried unexploded ordnance (UXO) originally developed for the DoD.

This work has two modes of operation. In the first, an in-pipe beacon (or sonde) provides geo-referenced 3D locations of the traversing in-pipe inspection/repair robot. Integrated with the robot, the 3D electromagnetic transmitter acts as a real-time homing beacon that is tracked by APEX (in receiver mode) on the surface for precise localization. In the second mode of operation, APEX runs in both transmit and receiver mode without the sonde. APEX uses both a transmitter and a receiver array to provide subsurface 3D pipe localization, typically within 4-inch accuracy, geo-referenced and ready for geographic model integration. Additionally, APEX provides pipe diameter classification, adding to the rich dataset for subsurface utility engineering (SUE) applications. For both operational modes, WRT is developing a comprehensive toolset for efficient and streamlined APEX deployment, including a simple and intuitive operating software package, pre-planned deployment transects with shapefile overlays for spatial analysis, real-time visual data display, and in-field real-time and near-time results. For geo-positioning flexibility, APEX has been fully integrated with survey-grade GPS, robotic total station, and simultaneous location and mapping technologies.

Ongoing field trials are demonstrating APEX to be a useful, modern, and capable tool for several SUE applications. To learn more, please contact Jack Foley: foley@whiterivertech.com.

PIPELINE INSPECTION PLATFORM ROBOT

As part of ARPA-e's REPAIR program, Plitzie is developing a highly mobile and flexible mapping and pipeline inspection platform robot that can mount a variety of sensors or inspection tools and eventually would run inside live pipe. Plitzie's third generation biomimetic robot can handle high angle turns, debris, and tight spaces to inspect pipeline system health or improve location data/mapping in natural gas or other piping systems. The recent addition of a detection capability for diameter and ovality allows for health monitoring of changes that may be more subtle or over longer distances. Plitzie is initiating industry demos to provide on-site inspection information and offline data for analysis. Demonstration partners, either service providers or utilities, or sensor groups in need of a delivery platform for operation in pipe sizes from 4-10 inches diameter can contact Plitzie (info@plitzie.com) to learn more.



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.*

California Energy Commission:
Locating & Mapping Research & Development

"The safety and integrity of underground gas pipelines rely on the availability and accuracy of pipeline location information… It is essential to develop and demonstrate novel and advanced systems that can locate pipelines accurately; process, analyze, and visualize data in real-time; and map the subsurface pipeline in all three dimensions."

-California Energy Commission-

"Excavation damage is among the primary causes of pipeline damage. To help address this issue, we must develop and enhance locating technologies that can demonstrate more accurate real-time data collection and analysis of subsurface gas pipeline location information prior to excavation."

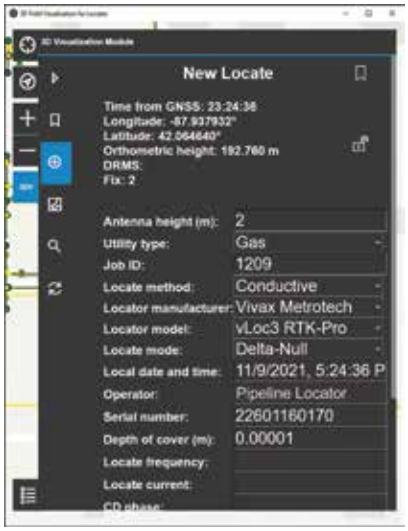
-Angela Gould – Assistant Deputy Director, Energy Research and Development Division, California Energy Commission

3D Visualization Software for Mapping Underground Pipelines and Improving Pipeline Asset Management

By: Jason Sphar, Gas Technology Institute (GTI)

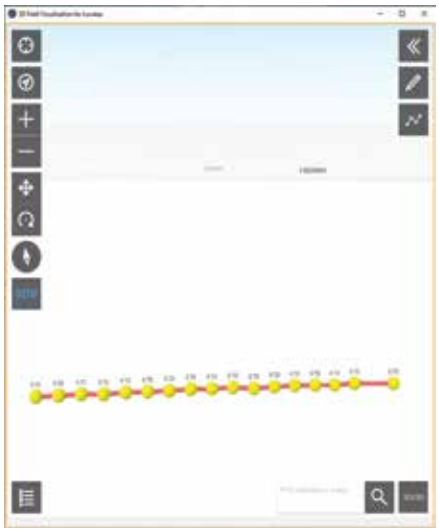
"The utility industry can benefit from the digital collection, storage, and visualization of underground assets for better safety, planning, and pre-construction purposes." -GTI-

In the California Energy Commission (CEC) project titled *"3D Visualization Software for Mapping Underground Pipelines and Improving Pipeline Asset Management,"* Gas Technology Institute (GTI) created a field-based application to collect, store, and visualize underground gas infrastructure in 2D and 3D formats. The application allows utility locate personnel to utilize existing electromagnetic (EM) and ground-penetrating radar (GPR) devices paired with internal and external GPS/GNSS to collect and store utility locates in a digital GIS format. Users can add their own 3D enabled utility GIS data to a cloud-based map or read existing



Locate Form Image


Spatial Query for Locator Assistance


Utility Locate 3D

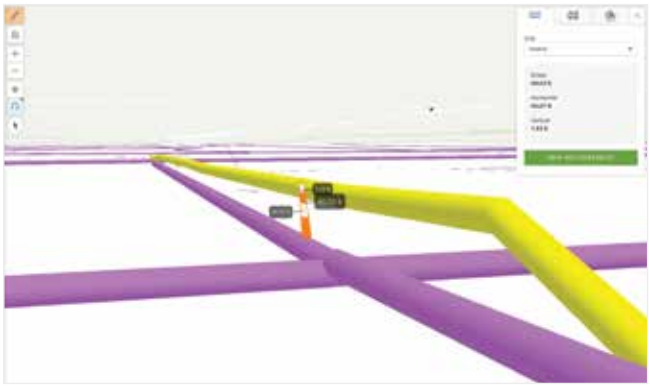
utility locate points from a file to record information that may have been previously collected but never mapped.

Newly performed locates will be displayed alongside existing gas utility GIS data and are accessible to the field user in real-time. Users can toggle between traditional 2D maps and 3D scenes to visualize the utilities above and below ground.

The user performs a spatial query to retrieve valuable information about site conditions. Results from this query may include surrounding soil types, GPR device penetration suitability, gas lines sharing a trench with other utilities, and pipe features affecting the signal during a locate.

Operators also have access to complete a smart-form for documenting site conditions they want to record during the locate process. Site conditions can provide insight on bad tracer wire or a recorded geo-point indicating an access point for connecting and applying a signal to a pipe. The site conditions are also stored in a GIS format and visible on the application's map. The documented conditions will provide helpful tips for future locators and help improve the locate process's efficiency by providing more transparency of the project site.

This software application will participate in a six-month pilot demonstration at various sites within the state of California to gauge performance and potential needs for future stages of development.



Existing Utilities 3D

ABOUT THE AUTHOR:

***Jason Sphar** is GIS Analyst II for the Gas Technology Institute and has been working in the natural gas industry for the past six years.*

Enhanced Locating Technologies for Underground Pipelines with Better Accuracy

By: Kaushik Biswas PhD, Gas Technology Institute (GTI)

"This project aims to demonstrate how combining the best-in-class technology can provide a holistic solution to identify and map underground pipelines, improving the safety and integrity of a gas utility infrastructure." -Ryan Hagensee – Smart Utilities Program Manager, GTI

One of the leading causes of damage to underground pipelines is directly related to locating issues. Due to depth of cover, type of ground cover, pipe material, pipe size, soil moisture, and proper equipment operations, it is difficult to accurately locate underground gas infrastructure. This California Energy Commission-funded project will develop and demonstrate an enhanced natural gas pipeline locating technology that improves the accuracy of locating pipelines over current practices and technologies. The enhanced locating technology will utilize adapted and improved above-ground large standoff three-dimensional electromagnetic (3DEM) detection technology and an in-pipe gyroscopic mapping device. The project team consists of Gas Technology Institute (GTI), White River Technologies (WRT), and Trident Engineering.

The primary technology of interest is WRT's APEX technology featuring innovative 3D illumination and detection of subsurface targets using three-axis transmitters. Figure 1 shows the APEX electromagnetic induction sensor for obtaining accurate localization and characterization of subsurface metal objects, including natural gas pipes and other utilities. The APEX sensor head comprises an array of induction coil transmitters that generate multi-directional, low-frequency magnetic fields below

Figure 1. APEX Advanced 3D Sensor is a Person-Portable System Developed to Detect and Characterize Subsurface Objects

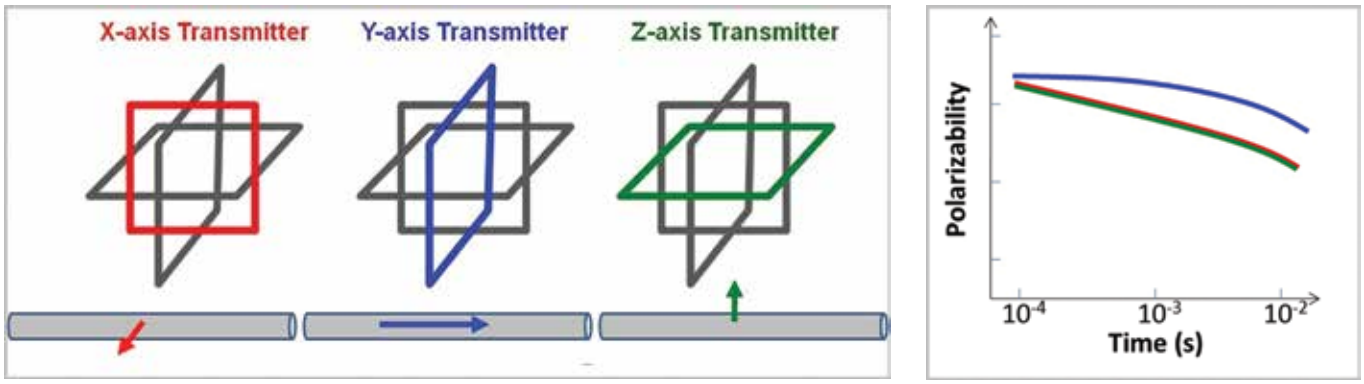


Figure 2. LEFT: Each Transmitter Creates a Unique Polarization of the Pipe that is Determined by the Direction of the Magnetic Field Impinging on the Pipe. RIGHT: Overall Response of the Pipe to the Transmitters can be Deconstructed into Principal Components Described by a Set of Three Time-Dependent Principal Electromagnetic Polarizabilities

the ground surface. When the transmitter field impinges upon a metal object, such as a pipeline, it induces eddy currents on the object's surface. These eddy currents rapidly decay and generate a time-varying secondary magnetic field that is sensed by the APEX receivers, which comprise an array of 3-axis induction coils

Figure 3. Aerial Image of Installed Pipe System from a Drone (Top of the Image is Facing East)

that measure the vector components of this decaying field across the swath of the APEX sensor head. As the transmitter fields impinge on the pipe in different directions, these responses can be deconstructed to represent the polarization of the pipe's principal axes. The responses of these principal axes to the impinging magnetic fields are known as the time-dependent electromagnetic polarizabilities of the pipe, as shown in Figure 2. These features can characterize physical attributes such as pipe diameter, wall thickness, and material composition.

Initially, GTI and Trident Engineering performed a baseline evaluation of the capabilities and performance of three existing, non-intrusive commercial off-the-shelf electromagnetic sensors. The baseline evaluation included a technical review of each commercial locating tool followed by a field calibration survey to document the 3D positional accuracy of mainstream sensors, with a particular emphasis on vertical positional accuracy. The field survey was performed in GTI's "pipe farm", where GTI designed and installed a brand-new pipe system with known 3D spatial coordinates shown in Figure 3. Next, the APEX system was demonstrated at the GTI pipe farm to evaluate its accuracy in locating and mapping pipelines. WRT is currently improving the APEX algorithm and analyzing the survey data from GTI's pipe farm seen in Figure 4.

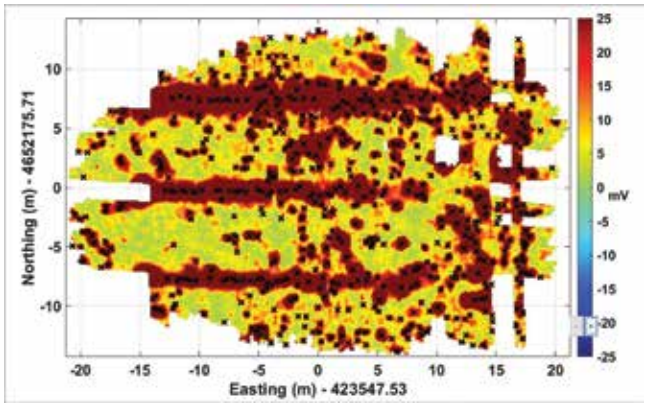


Figure 4. Electromagnetic Anomaly Heat Map – APEX Solution Survey Data from GTI Pipe Farm

For the next phase of the project, the project team is developing a Pilot Demonstration Plan and working with two California gas utilities to identify suitable locations for field demonstrations of the APEX technology and an in-pipe mapping and locating tool.

ABOUT THE AUTHOR:

Kaushik Biswas, PhD *has 15+ years of experience managing multi-partner projects funded by DOE, DOD ESTCP, California Energy Commission and the industry, with responsibilities including technical leadership, interactions with sponsors, and financial and technical progress reporting. His communication and outreach skills are demonstrated via numerous journal publications (650+ citations and h-index of 14 per Google Scholar), conference presentations and presentations to sponsors and in stakeholder meetings.*

Detection and Tomographic Visualization of Buried Pipelines

By: Khosrow Bakhtar, Bakhtar Research and Engineering LLC

Research and field tests being conducted on developing a novel detection and tomographic visualization for mapping subsurface pipelines under sponsorship of California Energy Commissions and PHMSA. The technology is based on combining low-power Radar (less than 10 dBm) and Forced-Resonance-Imaging (FRI) principles referred to as Bakhtar buried Pipe Detector (BPD). The technology will be utilized to collect, screen, analyze, manage, and integrate pipeline location data from multiple sources, such as utilities, locating service providers, and 811 organization. The BPD main hardware components consist of a low-power (less than 10 dBm) source Vector Network Analyzer (VNA), a pair of FR dipole/horn antennae, an integrated RTK GPS, a small tractor hauling the antennae, transmission lines (TL), data acquisition and control units shown in the inserted figure.

Test bed interrogation is done by moving forced resonating (FR) antennae at constant slow speed over the area of interest, collecting sub-surface data, detecting buried pipeline location followed by constructing tomographic image from underground targets (pipelines) in a rapid succession. The FR antennae are capable to transmit low-power electromagnetic waves into any geologic formation including salt saturated test beds and ocean floor. The results of mapping will provide uniquely defined high-resolution information on location and alignment, depth, type (metallic and/or plastic pipes), dimensional details and alignment of buried pipelines. This information along with surface footprint (from GPS) coordinates of buried pipelines will facilitate ease of detection and location identification for field crews. Bakhtar Research and Engineering will work with the stakeholders, develop a user acceptance report, and continuously update the software based on the user inputs.

It should be noted that original platform for the BPD with FRI capability was developed under US Air Force SBIR programs Phases, 1, 2, and 3 (Bakhtar, 2001), referred to as "*BakhtarRadar.*" The *BakhtarRadar* will be modified for almost real-time (same day results presentation pipelines detection followed by tomographic mapping and volumetric image reconstruction. The technology will also establish connections directly or via cloud service so that field data can be processed in timely manner. Furthermore, the technology will have capability to integrate other information for pipeline management and damage prevention, maintenance history and survey results.

ABOUT THE AUTHOR:

Khosrow Bakhtar *is the inventor of the technical approach of absorption of energy at the quantum emission bands and forced-resonance imaging as a concept for subsurface imaging applicable to buried pipeline detection and 3-D visualization. He has published more than 250 papers and technical reports in the field of applied science and electromagnetics. Dr. Bakhtar completed his basic engineering training in the United Kingdom and graduate studies in the United States.*

Cadent Gas Trial of Air-Vortex Applied Epoxy Reestablishes Gas Supply to a Historic Building in London

By: Steve Medley & Grant Whittle, Nu-Flow Technologies Inc.

UTILITY BACKGROUND

Cadent Gas is the largest gas utility in the United Kingdom, providing gas to 11 million homes and businesses. Cadent's employees strive to fulfill their mission "to keep people warm whilst protecting the planet." As gas pipes continue to reach and even exceed their original design life expectancies, keeping customers supplied with gas can be challenging while remaining in compliance with all UK regulatory requirements.

UK Gas Transporter Licenses require the Gas Distribution Networks (GDNs) to have a common Network Asset Risk Metric Methodology (NARM). UK GDNs are also required to comply with the performance-based RIIO (Revenue = Incentives + Innovation + Outputs) regulatory framework to keep rates reasonable and to reward utilities for successful innovation. Associated regulatory price controls can thereby place budgetary limits on available and viable network maintenance options when issues do arise. All GDNs in the UK are implementing Asset Management Plans to ensure long-term sustainable operations while complying with the NARM regulatory requirements.

THE CHALLENGE REQUIRING AN INNOVATIVE SOLUTION

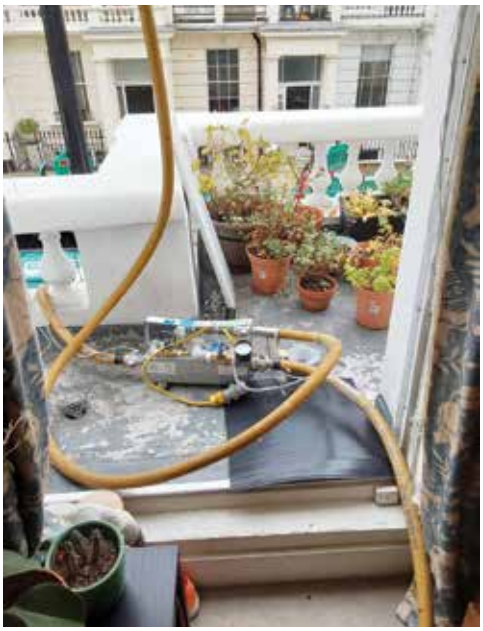
A key issue actively being addressed by gas companies around the world is leaking joints in aging metal gas system pipes. For example, old lead yarn joints in the buried pipes are known to dry out and cause gas leaks. Likewise, leaks also develop from the breakdown of PTFE paste or pipe sealant used on the pipe threads in the building pipes. Such leaks result in loss of gas which can also be non-revenue if lost before the meter. Furthermore, gas leaks contribute considerably to greenhouse gas emissions. And of course, when gas leaks occur within the confines of the building envelope, dangerous gas accumulation can potentially develop. As the associated risks are becoming better understood, monitoring for leaks is increasingly regulated in GDNs around the world.

The gas leaks within the buried distribution system have been proactively addressed by Cadent through the addition of monoethylene glycol to swell the old joint sealant to help reseal the joints until the buried pipes can be replaced. Eventual distribution pipe replacement with modern plastic gas pipes is part of the long-term Asset Management Plan of UK and North American GDNs. However, not all pipes in gas systems are ideal candidates for pipe replacement.

The gas pipes in many older private buildings continue to leak excessively, because the dried out paste joint seals used in building pipes are not corrected by the use of the systemic monoethylene glycol treatment of the buried distribution pipe joints. Ofgem deploys the Health & Safety Executive who issues the Safety Case to building owners who are responsible for leaks in their private building gas pipes and the gas companies are required to disconnect service on buildings where leakage has not been adequately precluded.

> *"The project also helps to future proof the infrastructure against the planned introduction of hydrogen gas."*

Gas companies are required to disconnect service on buildings where leakage has not been adequately addressed



Epoxy heating unit

PROJECT BACKGROUND

A multi occupancy historic town house in Pimlico, Westminster, London had its gas supply cut off due to a leaking supply pipe below ground in the basement flat of the 5-story building. This building is within a conservation area and is Listed Grade 2, which is defined as "of special interest, warranting every effort to preserve it." As part of the planning conditions of the "listed status" building, pipework is not allowed to be run on the fascia of the building. This precluded Cadent's preferred option which was to position five separate meter boxes in the entranceway to the basement flat and to run outlet pipework to each of the different meter points on each of the stories.

With little other option, Cadent took the opportunity to commission a trial project with a scope to implement and assess the capability of an innovative alternative solution to this pervasive issue of rehabilitating leaking gas pipes within buildings.

ASSET MANAGEMENT GOALS OF THE PROJECT

At the Strategic Level, Cadent relied upon this trial project to improve their understanding of the applicability and attractiveness of NuFlow's System 945 (an air-vortex applied epoxy internal coating), as compared with other available solutions for leaking building pipes connected to their Gas Distribution Network (GDN). As described by Chris Rison, Head of London Investment Planning Office at Cadent Gas Limited, "the trial project was designed to help define the opportunities and appropriacy of utilizing [air-vortex applied epoxy] within both the GD2 context (i.e. NARMs current framework outputs and constrained finances), and with Cadent's aspiration for compliance with future more restrictive GD3 [governance]. This trial project was also designed to contribute to the required evidence base to justify prospective future use of the [air-vortex applied epoxy technology]. Cadent intends to test the innovative technology on a range of building types, and especially higher risk buildings, so that asset health issues can be addressed and monitored during the trials."

TACTICAL MANAGEMENT GOALS OF THE PROJECT

At the Tactical Level, the historic "English Heritage" London town house associated with this project is listed as Grade 2. Replacing the existing gas riser pipes while preserving the architectural integrity of the building would have been difficult, expensive, and would have resulted in prolonged disruption to the building's gas service. As explained by Mr. Rison, "With the [air-vortex applied epoxy process], we could refurbish the section of pipework within the concrete slab which would remove the need for extensive, unsightly boxing and ventilation throughout the basement flat." Air-vortex applied epoxy can seal the gas riser pipe from leaking while not adversely impacting the architectural integrity of the historic building, and while avoiding otherwise unavoidable and significant adverse budgetary impacts resulting from historic restoration requirements for such a Grade 2 building.

OPERATIONAL MANAGEMENT GOALS OF THE PROJECT

Customers in the historic town house had been disconnected from their gas supply because of leakage within the basement vault. Restoring service in a timely, proactive manner that would satisfy the customers was a top operational priority. Under the UK oversight framework, Ofgem (Office of Gas and Electricity Markets) requires customer satisfaction (C-Sat) surveys to monitor the performance of GDNs. The goal of all such customer interactions is to achieve at least an "8 out of 10" during such surveys.

For this project, the other technologies considered were "cut and test" and an anaerobic riser fogging technology, but each was found to be unsuitable for this application. Mr. Rison elaborated that "an external rebuild option [would have been] very difficult to achieve. This would have also led to the customers being off gas for a substantial amount of time." Cadent went into this trial performance project with the belief that this new and innovative air-vortex applied epoxy process could help stay within budgetary constraints while simultaneously better addressing the customer needs and more effectively limiting customer disruption, thereby significantly enhancing the resulting customer satisfaction.

TECHNOLOGY VALIDATION & VERIFICATION

Long before this trial project was considered, NuFlow spent several years working with the UK gas industry to validate and verify the air-vortex applied epoxy coating technology to properly qualify for use.

Elimination of cissing and pin-holing risks through improved resin chemistry was key to achieving approval, as was development of software controls to preclude installation when site parameters (such as temperature and humidity) were not within allowable tolerances. Hold and inspect points were established at critical stages and automated detailed project reporting requirements were incorporated into the system software. Equipment calibration and certification requirements were established, as were personnel training and certification requirements.

After a thorough technical evaluation conforming to Report 10966 - Second Issue, Cadent Gas granted technical approval for use of the NuFlow [System 945] gas riser lining technique on May 10th, 2020.

Air-vortex applied epoxy has the ability to seal the gas riser pipe from leaking

DETERMINATION TO PROCEED WITH TRIAL PROJECT

Cadent was faced with limited viable options for stopping the gas riser leak in this historic London town house. Having reviewed this innovative alternative technology's fit to the Strategic, Tactical, and Operational needs of the project, and having considered the thorough industry validation and verification of the materials and methods, Cadent chose to proceed with the trial of the air-vortex applied epoxy as the best available alternative and perhaps the only viable solution. Air-vortex applied epoxy was recognized by Cadent as offering a less intrusive process, quicker restoration time, and an aesthetically neater outcome for the historic building and its occupants.

PROJECT IMPLEMENTATION

Parking suspensions and permits to situate vehicles and equipment were applied for in advance to facilitate the delivery process when the crew would arrive on site. Comprehensive site surveys and detailed pre-commencement meetings successfully ironed out prospective challenges beforehand.

Brian McNamee, Technical Consultant with NuFlow, explains, "We surveyed the gas riser supplying the building and determined that we would be able to remediate the system for them. Working with the Networks' pre-enabling team, we created a Method Statement, Safe System of Working and associated Bespoke Risk Assessment. These were approved."

The air-vortex equipment was 3rd party calibrated and certified immediately before use on the project. Members of the crew were also 3rd party trained and certified in the proper methods for air-vortex applied epoxy. On this project, achieving the required pipe cleaning and the specified anchor profile abrasion required a second air-vortex shot of abrasives.

Once this preparatory work was properly achieved, the air-vortex shot of resin proceeded as expected. Detailed site drawings made during the advance site survey assisted in pre-planning the shot. The required volume of resin was pre-calculated based upon the configuration and distance of the pipe sections to be coated.

Mr. McNamee further stated, "The work was duly undertaken and executed in the predicted 3-day window and handed back to the Network to re-commission."

PROJECT OUTCOME AND ASSESSMENT

"The team were well-briefed, and all were made clear on the objectives. NuFlow's project manager led the team well and all involved worked hard throughout the process," observed Mr. Rison. "The process was a success."

Mr. Rison stated he was "really impressed with all members of the team. The team acted professionally and kept me updated throughout the process."

In commenting upon the effectiveness of the project management, Mr. Rison clarified, "On a simplistic level, the success comes from comprehensive site surveys and organization. If the up-front work is thorough, it seems to me that the process is the simple part for the engineers on site."

Minimal surface disruption is a typical advantage of utilizing trenchless technology

> *"There were limited viable options for stopping the gas riser leak in this historic London townhouse."*

By using the air-vortex applied epoxy, Cadent was able to quickly restore service to this historic London town house without having to pay further compensation for unacceptable disruptions under the Ofgem Guaranteed Standards of Performance (GSOP). The customers living in the historic London town house expressed to Allan Dear, Operations Manager with NuFlow, that "They were delighted that their gas supply had been restored and were praiseworthy of the key role that NuFlow played."

Mr. Rison explained, "I think this process has a place within our scope of works. It will excel in areas with Grade 2 listing and difficult rebuild options. The great thing from our perspective is having the option available for the particularly challenging buildings." This less disruptive remediation technology can be accomplished where conservation constraints effectually preclude pipe replacement.

For such a small-scale project, "cut and test" or anaerobic riser fogging technology (had they been applicable) would have likely been lower cost, Mr. Rison also clarified. However, air-vortex applied epoxy is expected to be a more cost-competitive option on a larger scale project, such as compared to a 5-story riser build with scaffolding. Mr. Rison concluded from the trial project, "I think in the right scenario, [air-vortex applied epoxy] is a great alternative option for re-establishing gas supplies to multiple occupancy buildings (MOBs)."

FUTURE TRIAL AND RESEARCH NEEDS

Cadent is now working to accurately define how air-vortex applied epoxy can be positioned within their Decision-Making Tool for Gas Risers Solutions and are looking at how they can deliver successful outcomes working together with their planned mains replacement programs. Future projects are expected to also clarify how the air-vortex applied epoxy method can be utilized as a rapid reactive emergency response to riser supplies that have just been cut off.

When Cadent can implement pipe replacement with plastic pipe, such projects also help to future proof the infrastructure against the planned introduction of hydrogen gas; additional research is needed to better document whether epoxy coatings may likewise offer comparable retrofit compatibility with hydrogen gas.

BRINGING AIR-VORTEX APPLIED EPOXY COATING OF GAS BUILDING PIPES TO NORTH AMERICA

The extensive 3rd party validation and verification of the air-vortex applied epoxy technology in the UK greatly simplified development and passage of a North American ICC-ES Listing Criteria for the use of air-vortex applied epoxy coatings within gas building pipes. Based heavily upon the UK experience, LC-1045 "PMG Listing Criteria for Internal Epoxy Barrier Coating Material for Rehabilitation of Metallic Fuel Gas Pipe" was approved in December of 2020 preparing the way for building department approval for use across North America. PMG-1528 certifies the compliance of NuFlow's System 945 with LC-1045.

The engineering controls developed in consultation with the UK gas industry to minimize project risks, including 3rd party training of personnel and equipment certifications, are planned to be replicated for the North American market.

With recent L1B Visa approval of key UK trained and certified personnel to come to the USA, NuFlow is currently seeking trial project applications for the use of the air-vortexed applied epoxy technology for gas building pipes in North America.

ABOUT THE AUTHORS:

***Steve Medley** has been with Nu-Flow for 14 years starting out as a field technician, site supervisor and onto Project Management. He has been heavily involved in Research and Development projects within the company; one being Serline Lead Lining and the second Nuflow 945 Gas Lining.*

***Grant Whittle** has provided technical support on trenchless pipe rehabilitation projects for over 25 years. He has expertise in general management, team building, business development, technical sales, and marketing.*

REFERENCED STANDARDS

LC-1045 is exceptionally thorough, with extensive materials testing requirements, including the following referenced standards:

ASTM B117	Standard Practice for Operating Salt Spray (Fog) Apparatus, ASTM International
ASTM D543	Standard Practices for Evaluating the Resistance of Plastics to Chemical Reagents, ASTM International
ASTM D638	Standard Test Method for Tensile Properties of Plastics, ASTM International
ASTM D714	Standard Test Method for Evaluation of Blistering of Paints, ASTM International
ASTM D1434	Standard Test Method for Determining Gas Permeability Characteristics of Plastic Film and Sheeting, ASTM International
ASTM D2240	Standard Test Method for Rubber Property — Durometer Hardness, ASTM International
ASTM D2247	Standard Practice for Testing Water Resistance of Coatings in 100% Relative Humidity, ASTM International
ASTM D3167	Standard Test Method for Floating Roller Peel Resistance of Adhesives, ASTM International
ASTM D4541	Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers, ATM International (see alternative ISO 4624)
ASTM D5402	Standard Practice for Assessing the Solvent Resistance of Organic Coatings Using Solvent Rubs, ASTM International
ASTM E2105	Standard Practice for General Techniques of Thermogravimetric Analysis (TGA) Coupled with Infrared Analysis (TGA/IR), ASTM International
ASTM G62	Standards Test Methods for Holiday Detection in Pipeline Coatings, ASTM International
AWWA C210	Liquid-Epoxy Coating and Lining for Steel Water Pipe and Fittings, American Water Works Association
CAN-CSA-Z245.20	Plant-Applied External Coatings for Steel Pipe, CSA Group
ISO 8503-1	Preparation of steel substrates before application of paints and related products — Surface roughness characteristics of blast-cleaned steel substrates — Part 1: Specifications and definitions for ISO surface profile comparators for the assessment of abrasive blast-cleaned surfaces, ISO

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Stay tuned for more information.

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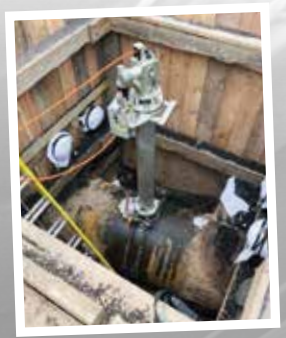

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