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TRENCHLESS NORTH AMERICA

The Official Magazine of the North American Society for Trenchless Technology

WINTER TECHNICAL EDITION

NASTT 2024 NO-DIG SHOW TECHNICAL PROGRAM PREVIEW

WINTER 2024
Volume 14 • Issue 1

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TRENCHLESS NORTH AMERICA

The Official Magazine of the North American Society for Trenchless Technology

WINTER 2024 – VOLUME 14, ISSUE No. 1

NASTT 2024 NO-DIG SHOW TECHNICAL PROGRAM PREVIEW!

For the first time, the heavily populated Northeast region is hosting the annual NASTT premier event – the largest trenchless technology conference and trade-show in the world. The No-Dig Show motto "Green Above, Green Below" exemplifies the position of trenchless technology as an important steward of our environment. Join us April 14 – 18 2024 and be part of the excitement as an attendee, presenter, sponsor or exhibitor! A preview of the Technical Presentations that form the core of the No-Dig Show.

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APRIL 14-18 | PROVIDENCE, RI
NO-DIG SHOW 2024

FEATURES

DEPARTMENTS

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GREEN ABOVE.
GREEN BELOW.

"We are proud to have launched our updated website!"

WELCOME TO THE WINTER 2024 EDITION OF

TRENCHLESS NORTH AMERICA!

This edition is the first of a now quarterly issue of Trenchless North America, providing a focus on technical subjects within the trenchless technology industry. This is one of several new initiatives that NASTT are undertaking this year, delivering on increasing Member Benefits as part of the upcoming 2024-2027 Strategic Plan which is based on your responses in the recent Membership Survey.

Inside you will find featured two full Technical Papers from No-Dig Show as well as abstract highlights from No-Dig North, recently held in Edmonton. Additionally, this edition's Q&A features WESTT Chair Kate Wallin and Morty's Trenchless Academy highlights our friends at Vermeer.

After many months of hard work we are also proud to have launched our updated website. This integrates the No-Dig Show and Membership Database along with many new features as well as improved technical library and search functions. There are several other exciting updates that we will bring to you over the coming months as part of this process and I would especially like to thank Jenna Hale, our Marketing Manager for her dedication in delivering this project. Our ambition is to have everything 'one click away'!

Please also take time to visit the Membership portal through **www.nastt.org** and update your profile. This enables us to send you relevant information about the issues important to you as well as the providing discounted rates to many of our publications and events.

We congratulate and welcome Brian Avon (Carollo Engineers), Kevin Bainbridge (Robinson Consultants), John Kraft (Louisiana Tech), Carl Pitzer (Thompson Pipe) and Eric Schuler (Onondaga County) as newly elected to the NASTT Board of Directors and look forward to their contribution in guiding our society during their terms of office.

You too can be involved as we encourage participation on our various committees – especially from non-Board members. It is important we are both as diverse in our member representation as possible and provide the opportunity for greater participation in our activities and being more involved. We have created new Membership and Industry Advisory committees to contribute to the direction of our activities and welcome contributions on our working groups reviewing and updating our range of Good Practice publications and courses.

Finally, a big thank you to the authors and review teams currently working on updating the editions of the Horizontal Directional Drilling and Cured-In Place Pipe publications and courses – we look forward to announcing and releasing these soon as part of our program of updating and expanding our Good Practice series.

To all of you who volunteer and contribute to making NASTT continue to improve and thrive, thank you.

If you have a great idea or suggestion, then we are always pleased to hear about it!

Enjoy your read!

Matthew

Matthew Izzard, Executive Director
North American Society for Trenchless Technology (NASTT)
mizzard@nastt.org

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TOGETHER WE ARE SHAPING THE FUTURE OF OUR INDUSTRY

Dear NASTT Members and Trenchless Advocates:

We are kicking off the new year with some exciting developments within our community, reflecting our commitment to staying at the forefront of advancements in trenchless technology. This new winter issue of ***Trenchless North America*** magazine marks our growth to a quarterly publication and spotlights the incredible strides and breakthroughs in technology that are shaping our industry. From cutting-edge innovations to insightful analyses, this edition promises to be a testament to the dynamic landscape we operate in. We are featuring two full technical papers chosen from some of the highest ranked papers presented during the 2023 No-Dig Show, as well as four abstracts from the recent No-Dig North conference held in Edmonton. You will learn more about organizations in our industry in our Eye on Industry, Q & A, and Morty's Trenchless Academy column.

In addition to the magazine release, I am looking forward to our upcoming conference, the NASTT 2024 No-Dig Show, where we will have the opportunity to delve deeper into the realm of trenchless technology. The conference will feature technical paper presentations from experts and thought leaders, providing a platform to explore the latest research and developments in our field. This event promises to be a source of inspiration, knowledge exchange, and networking. Check out the pages that follow to learn more about the Technical Paper Schedule and other opportunities to learn while in Providence, Rhode Island, April 14-18.

"Our new website has been launched!"

As part of our commitment to growth, I am delighted to share that our new website has been launched! We've combined the NASTT website and the No-Dig Show website into one convenient location. The website will serve as a hub for information, resources, and a seamless platform for connecting to your membership record and benefits. This enhancement reflects our dedication to providing a modern and accessible experience for all. Read more in this issue and visit **www.nastt.org** to check it out.

I encourage each of you to actively participate in the upcoming conference, engage with the magazine content, and explore the features of our new website. Your involvement is vital to the success of our community, and I am confident that these initiatives will further strengthen our collective impact.

"Your involvement is vital to the success of our community!"

Thank you for your ongoing support and dedication to the North American Society for Trenchless Technology. Together, we are shaping the future of our industry.

Matthew Wallin

Matthew Wallin P.E., Chair
North American Society for Trenchless Technology (NASTT)

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Welcoming North America's Underground Infrastructure Community to the Populous Northeast!

"Be a part of the excitement as a presenter, sponsor and exhibitor!"

The North American Society for Trenchless Technology looks forward to hosting the 2024 No-Dig Show in Providence, Rhode Island April 14-18. Hosting North America's premier trenchless educational and networking event in the Northeast for the first time, presents a golden opportunity for the Northeast Trenchless community to showcase the progress it has made in utilizing trenchless applications as the preferred method for underground infrastructure construction in the Northeast.

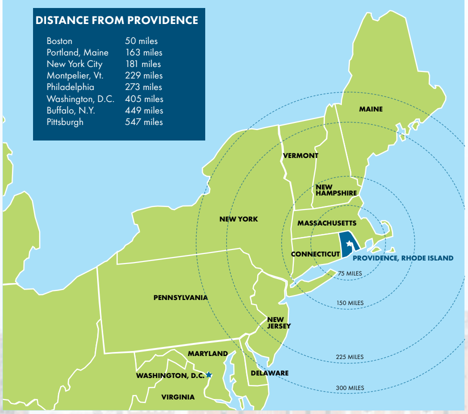
Within an easy day's drive from most cities in the populous northeast – Providence is just a few hours' drive from Portland ME, Philadelphia, PA, NY, NJ, VT and CT – the 2024 NASTT No-Dig Show promises to draw significant attention from top infrastructure decision-makers across the Northeast including municipal authorities, utilities, engineers, contractors, suppliers and policy-makers. The 2024 NASTT No-Dig Show motto "Green Above, Green Below" exemplifies the trenchless industry's position as an important steward of our environment and natural resources, utilizing approaches that have significant environmental and social benefits. Trenchless Technology is at the forefront of ongoing efforts to reduce GHG emissions.

Check the website www.nodigshow.com for registration, updates and further information. The excitement and anticipation is building - join us in Providence and be a part of the networking and learning!

Babs Marquis CCM
Delve Underground
2024 No-Dig Show Planning Committee Chair
Secretary, NASTT Board of Directors
Past Chair, NASTT-NE Chapter

APRIL 14-18 | PROVIDENCE, RI
NASTT NO-DIG SHOW 2024

The NASTT No-Dig Show is being hosted in the Northeast for the first time



Providence is an easy day's drive from most cities in the Northeast

APRIL 14-18 | PROVIDENCE, RI

NASTT NO-DIG SHOW 2024

See You in PROVIDENCE

2024

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Monday Morning

(Schedule up to date as of 2/7/24. Download the No-Dig Show app for the latest schedule.)

TRACK ▪ ROOM	TRACK 1 ▪ 556	TRACK 2 ▪ 555	TRACK 3 ▪ Ballroom B
TRACK TITLE	Microtunneling	HDD	Innovative Products
TRACK LEADER	DAVE SACKETT	PAUL BEARDEN	MATTHEW IZZARD
10:00 - 10:25	■ MM-T1-01 Tunneling on the Shores of Lake Erie: Microtunneling Challenges and Considerations through Soft Ground	■ MM-T2-01 Design and Construction of World Record 7,650-ft FPVCP HDD in Florida	MM-T3-01-04 Innovative Products Forum
10:30-10:55	■ MM-T1-02 Design and Construction of Six Microtunnels for GLWA 14 Mile Loop	■ MM-T2-02 New Subaqueous Trenchless Outfall in Long Island, New York - Overcoming Various Challenges to Completion	
11:00-11:25	■ MM-T1-03 Forcemain Twinning Made Possible by Microtunnelling	■ MM-T2-03 Understanding the Importance of HDD Radii	
11:30-11:55	■ MM-T1-04 Going the Distance: Microtunnel Keeps Golfers Swinging	■ MM-T2-04 Mitigating Instances of Pressurized Groundwater During HDD Construction	

Monday Afternoon

TRACK ▪ ROOM	TRACK 1 ▪ 556	TRACK 2 ▪ 555	TRACK 3 ▪ Ballroom B
TRACK TITLE	Large Diameter Tunneling	Pipe Jacking	Projects of the Year
TRACK LEADER	DON DEL NERO	SAM BRANCHEAU	MIKE KEZDI
3:30-3:55	■ MA-T1-01: A Tale of Many Tunnels: Challenges Urban Areas Creating a Network of Microtunnels to Connect a Large Diameter CSO Pawtucket Tunnel	■ MA-T2-01 Trenchless Shore Approaches: The Role of Pipe Jacking and Direct Pipe for Pipeline and Export Cable Landfalls	MA-T3-01-03 Projects of the Year Forum
4:00-4:25	■ MA-T1-02 Tunneling for Clean Solutions for Omaha	■ MA-T2-02 Implementing Multiple Trenchless Methods In Place of Open-Cut in Downtown Cleveland on the Shoreline Consolidation Sewer Project	
4:30-4:55	■ MA-T1-03 Stormwater Tunnel Extension	■ MA-T2-03 Trenchless Replacement of Aging Sewer Trunk Main in Sonoma, California	

TRACK 4 ▪ Ballroom D	TRACK 5 ▪ 552	TRACK 6 ▪ 551
Pipe Ramming & Pipe Jacking	CIPP	Water Main Rehabilitation
ANIL DEAN	AMBER WAGNER	GEORGE RAGULA
■ MM-T4-01 Getting Hammered at 8,500 Ft.	■ MM-T5-01 Detailed Parameter Sensitivity Analysis and Practical Ramifications for Assessment and Design using the ASCE MOP 145- Design of Close-fit Liners for Gravity Sewers	■ MM-T6-01 Repair of 78-in. and 102-in. PCCP Aqueducts by Sliplining Using Centrifugally Cast, Fiberglass-Reinforced, Polymer Mortar Pipe (CCFRPMP)
■ MM-T4-02 Pipe Hammering Underneath a Class 1 Railroad for New Drainage	■ MM-T5-02 The CIPP Quality Assurance Paradox	■ MM-T6-02 Case Study of a New AWWA Class IV Lining System for PCCP
■ MM-T4-03 AMICI Engineering Contractors Dual Conductor Barrels Help Facilitate Potential Record-Breaking HDD Project	■ MM-T5-03 Big Liners in Small Spaces: Rehabilitation of a 120-Year-Old, 54-in. Brick Interceptor in Lawrence, Massachusetts	■ MM-T6-03 Emergency Interconnection Rehabilitation at the Sakonnet River
■ MM-T4-04 Reducing Flood Risk Through North America's Largest Microtunnelling Installation- The NWIC Upper Plateau Separation Project	■ MM-T5-04 Cured-In-Place Pipe (CIPP): A Proven Systems Technology	■ MM-T6-04 St. Paul Regional Water Services: Developing a Self-Performing Pipe Bursting Program

TRACK 4 ▪ Ballroom D	TRACK 5 ▪ 552	TRACK 6 ▪ 551
Emerging Technologies	I/I	Project Planning & Delivery
DAVE KOZMAN	CATHY MORLEY	GUS O'LEARY
■ MA-T4-01 How One Texas Municipality Implemented a New In-line Inspection Technology to Inspect a Critical Raw Water Line	■ MA-T5-01 High-Build Epoxy Rehabilitates Critical 100-Year-Old Structure in Downtown Boston	■ MA-T6-01 It Didn't Include Quantities - Advantages and Disadvantages of Indefinite Deliverable/ Indefinite Quantity (IDIQ) Contracts for Trenchless Sewer Rehabilitation
■ MA-T4-02 Introduction to Manufactured In-Place Composite Pipe (MICP)	■ MA-T5-02 Implementation of a Multi-Year I&I Source Reduction Improvements Program in Allentown, Pennsylvania	■ MA-T6-02 Laguna County Sanitary District Asbestos Abatement UV CIPP Rehabilitation Through Protected Environments in Santa Maria, California
■ MA-T4-03 How to Select New and Emerging Technologies for Real Time Pressure Pipeline Condition Monitoring	■ MA-T5-03 SIPP: Minimizes Disruption Repairing Pinhole Leaks in Distribution Water Main Pipes	■ MA-T6-03 Free Swimming Electromagnetic Assessment of Raw Water Pipeline Provides Critical Baseline Data

Technical Sessions

■ Water ■ Water/Wastewater ■ Wastewater ■ Gas ■ Electrical

Tuesday Morning

TRACK ▪ ROOM	TRACK 1 ▪ 556	TRACK 2 ▪ 555	TRACK 3 ▪ Ballroom B
TRACK TITLE	Geotechnical Issues	HDD	Emerging Technologies
TRACK LEADER	DENNIS DOHERTY	KATE WALLIN & MARY NEHER	DAVID HAUG
8:00-8:25	▪ TM-T1-01 Outside the Box Geotechnical Data Collection Approaches for Trenchless Crossings	▪ TM-T2-01 Drilling in Paradise: The Race to Replace Aging Pipelines along Florida's Oldest Causeway	▪ TM-T3-01 Emergency Trenchless Rehabilitation of the East Don River Trunk Sewer and the Highland Creek Interceptor
8:30-8:55	▪ TM-T1-02 Trenchless Replacement of Aging Force Main in the Russian River Gorge	▪ TM-T2-02 Drilling Down to Eliminate Overflows	▪ TM-T3-02 The Use of a Geo Pilot Bore to Confirm HDD Feasibility
9:00-9:25	▪ TM-T1-03 A Novel Approach to Geotechnical Data Collection and Development of Civil 3D Subsurface Model for Large Scale Trenchless Shore Approaches	▪ TM-T2-03 Pulling HDPE and RJ-DIP in One HDD Installation	▪ TM-T3-03 Concept for Jet-based Thermal Spallation Boring for Trenchless Tunneling in Challenging Hard Rock Geologies
9:30-9:55	▪ TM-T1-04 Ensuring Global Stability Around Large Diameter Structures In Conjunction With Sliplining & CIPP Rehabilitation	▪ TM-T2-04 Perkins Avenue: A Community Benefits Long-Term from HDD	▪ TM-T3-04 The Pittsburgh Water and Sewer Authority (PWSA) Large Diameter Sewer Rehabilitation with Geopolymer Lining System (GLS) Mortar
10:00-10:25	▪ TM-T1-05 The Execution of GBRs on Trenchless Projects - Are They Working?	▪ TM-T2-05 Design-Build Coordination and Management Plan for the Bay Park Conveyance Project Delivery with Dual Trenchless Construction Methods in New York	▪ TM-T3-05 Direct Steerable Pipe Thrusting for Land-to-Water Installations in an Emerging Renewable Energy Market
10:30-10:55	▪ TM-T1-06 Hydraulic Fracture Analysis: Evaluating the Applicability of the Delft Equation Under Undrained Conditions	▪ TM-T2-06 Differing Site Conditions Claims: Contractor's Right to Rely on Soils Data	▪ TM-T3-06 Trenchless Solutions for Small-diameter Pipeline Installations

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TRACK 4 ▪ Ballroom D	TRACK 5 ▪ 552	TRACK 6 ▪ 551
Renewables	Condition Assessment	Wastewater Pipeline Rehabilitation
GABE GARCIA	MARK WADE	GEORGE KURZ
■ TM-T4-01 South Fork Wind: Bringing Offshore Energy to Shore	■ TM-T5-01 Force Main Condition Assessment: A Treatise from an Owner, Consultant and Industry Point of View	■ TM-T6-01 MID Segment 5 Rehabilitation: Innovative Debris Removal, Spray Lining and Sliplining of a Large Diameter Sewer Without Interrupting Service
■ TM-T4-02 TBA	■ TM-T5-02 How to Effectively Perform a Pipeline Health Check for Sewer Force Mains	■ TM-T6-02 First Aqueduct Treated Water Tunnels Rehabilitation for Domestic Water with GeoSpray Geopolymer for San Diego County Water Authority (SDCWA)
■ TM-T4-03 ASTM F1962-HDD Standard Guide for Placing Polyethylene Pipe-Recent Additions and Status	■ TM-T5-03 Visual Inspection & CFRP Strengthening of CIP Liner - The West Trunk Sewer Pipe in Mississauga, Ontario	■ TM-T6-03 Rehabilitating a 48-in. Brick Sewer Under a Mass Transit Right-of-Way
■ TM-T4-04 Best Practices for Safe, Efficient Shore Approach Design and Construction	■ TM-T5-04 Three Case Studies Covering All Aspects of Pressure Pipe Condition Assessment	■ TM-T6-04 Choose Wisely: Trusting Permanent Shotcrete Lining to Preserve a Northeast Ohio Culvert
■ TM-T4-05 Sioux Falls Replaces Nearly a Mile of Large Diameter Ductile Iron Pipe via Pipe Bursting	■ TM-T5-05 Determining Maintenance Strategies for Large Diameter Water Pipelines using RCM	■ TM-T6-05 Designing World's Largest Composite Pipe for Sliplining
■ TM-T4-06 Old, leaky and Hard to Access - Rehabilitating a 100-Year-Old Water Transmission Main	■ TM-T5-06 Inspection of a 50-Year-Old Outfall Forcemain to San Pablo Bay	■ TM-T6-06 The Lining Selection Tools between Cured-in-Place Pipe (CIPP) and Spray-in-Place Pipe (SIPP) Lining Methods

Technical Sessions

■ Water ■ Water/Wastewater ■ Wastewater ■ Gas ■ Electrical

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Tuesday Afternoon

TRACK ▪ ROOM	TRACK 1 ▪ 556	TRACK 2 ▪ 555	TRACK 3 ▪ Ballroom B
TRACK TITLE	Microtunneling	HDD	Pilot Tube Methods
TRACK LEADER	NORMAN CHAN	KYLE WILLIAMS	MICHAEL FLANAGAN
3:30-3:55	■ TA-T1-01 Trenchless Design Challenges and Real World Application in Aurora, Colorado	■ TA-T2-01 Challenges and Lessons Learned of Horizontal Directional Drills in South Florida	TA-T3-01-02 Northeast Trenchless Outlook Forum
4:00-4:25	■ TA-T1-02 Alternative Delivery and Trenchless Methods used to Install 60,000LF of Pipe on the Bay Park Forcemain Project	■ TA-T2-02 16-in. HDD Gas Pipeline Crossing of the Sacramento River in Rio Vista, California	
4:30-4:55	■ TA-T1-03 Microtunnel Specifications - Balanced Specifications and Lessons Learned	■ TA-T2-03 Double Trouble: A Tale of Twin Water Main HDD Installations with Two Pipe Types While Drilling in Tight Places	■ TA-T3-03 Navigating a 30-in. Hammer through 8-in. River Rock: A Utah Historic Winter Case Study
5:00-5:25	■ TA-T1-04 Microtunneling for Electric Cables in Providence: A Case Study	■ TA-T2-04 Determination of Geotechnical Parameters for Design of Horizontal Directional Drilling	■ TA-T3-04 Sanitary Sewer Projects Converted to Pilot Tube Method of Guided Boring

Wednesday Morning

TRACK ▪ ROOM	TRACK 1 ▪ 556	TRACK 2 ▪ 555	TRACK 3 ▪ Ballroom B
TRACK TITLE	Project Planning & Delivery	HDD	Safety
TRACK LEADER	KERBY PRIMM	KIM HANSON	MO NAJAFI & EHSAN RAJAEI
8:00-8:25	■ WM-T1-01 The Considerable Cost of the Burrowing Beetle	■ WM-T2-01 HDD Construction of a Large Diameter Pipeline Under the Oakland Inner Harbor and Though Soft Clays	WM-T3-01-02 Renewables in 2024 Forum
8:30-8:55	■ WM-T1-02 Pullback Lift Considerations for Horizontal Directional Drills	■ WM-T2-02 Golden Ears Forcemain River Crossing Project: Lessons Learned from HDD and Pipe Ramming Crossings	
9:00-9:25	■ WM-T1-03 Dickenson Road	■ WM-T2-03 Highlights of the High Life - Miami Beach's Horizontal Directional Drill Case Study	■ WM-T3-03 Seismic Design of HDPE Pipe
9:30-9:55	■ WM-T1-04 Options to help Owners Manage Budgets in Volatile Markets	■ WM-T2-04 Completing a Short but Challenging HDD River Crossing to Install a 30-in. HDPE Bundle in Mixed Subsurface Conditions	■ WM-T3-04 Unique Considerations for Cable System's Landfall HDD Planning and Design

TRACK 4 ▪ Ballroom D	TRACK 5 ▪ 552	TRACK 6 ▪ 551
Inspection	CIPP	Sliplining
STEPHEN WELLING	ANDREW COSTA	STEPHANIE NIX
■ TA-T4-01 The Perils of Surcharging Interceptors: Unintended Consequences of In-line Storage	■ TA-T5-01 Factors Controlling the Ability of Polymer Liners to Prevent Pipeline Leakage Under Differential Ground Movements	■ TA-T6-01 LS 23 Force Main Upgrades by HDD & Slipline
■ TA-T4-02 Characterization of Critical Concrete Pipes Using Circumferential Waves	■ TA-T5-02 Emergency Force Main Repair Using Pressure CIPP	■ TA-T6-02 Advancements in Trenchless Technology: San Diego First Aqueduct Treated Water Tunnels Rehabilitation Project
■ TA-T4-03 Multi-Sensor Inspection: Assessing the Condition of Large Diameter Pipes With 3D LIDAR Modeling	■ TA-T5-03 A Twin Makes It Better! Rehabilitation of the McVean Trunk Sewer System, Regional Municipality of Peel	■ TA-T6-03 Rehabilitation of the Confluence of Two Large Diameter Interceptors in Macomb County, Michigan
■ TA-T4-04 How to Effectively Perform a Pipeline Health Check for Large Diameter Gravity Sewers	■ TA-T5-04 Halifax Water Akerley Forcemain Lining	■ TA-T6-04 Design Method of Pipeline in Shield Tunnel Crossing Fault

TRACK 4 ▪ Ballroom D	TRACK 5 ▪ 552	TRACK 6 ▪ 551
Gas	Trenchless Research	Asset Management
JIM MURPHY	RICHARD THOMASSON	CHAD ANDREWS
■ WM-T4-01 Innovations and Advancements in Liners for Positive Pressure Applications	■ WM-T5-01 Styrene Emission Evaluation: An Innovative Controlled Test Setup	■ WM-T6-01 A City's Ongoing Rehabilitation Program of Aging Sewer Infrastructure
■ WM-T4-02 Never Give Up: Completing a Challenging 2,000 ft HDD Beneath I-495/3 That Was a Decade in the Making	■ WM-T5-02 The Proper Order of Operations for CIPP Rehabilitation of a Collection System	■ WM-T6-02 18.6km Electromagnetic Inspection for the City of Winnipeg
■ WM-T4-03 Critical Aspects and Construction Challenges for the use of Direct Steerable Pipe Thursting (DSPT)	■ WM-T5-03 Sewer UV CIPP Rehabilitation on the River	■ WM-T6-03 Geopolymer or not Geopolymer? That is the Question of the Day from the Boston Water and Sewer Commission (BWSC)
■ WM-T4-04 Comparative Analysis of Load-Deflection Behavior and Crack Sizes in Repaired Pipe Specimens	■ WM-T5-04 An Investigation of Methods and Equipment Used to Measure Volatile Organic Compound Emissions during Cured-in-Place Pipe (CIPP) Rehabilitation	■ WM-T6-04 Difficult Watermain Pipe Bursting Project Along Shoreline Roadway in Connecticut

■ Water ■ Water/Wastewater ■ Wastewater ■ Gas ■ Electrical

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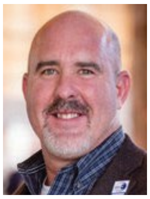
~ Eric Schuler, PE, Onondaga County Department Water Environment Protection



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~ Joe Lane, Aegion Corp.

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"I first joined NASTT to stay current on technological developments, best practices and market trends. Participating in NASTT committees and events and accessing its expert mentors and professionals is essential to the success of almost any project."

~ Marya Jetten, Jacobs Engineering Group

Amazing Network

"NASTT has been the most significant vehicle relative to the industry-specific connections I've made and cultivated throughout my career."

~ Cindy Preuss, PE, CDM Smith

Membership Helps Me Strut My Stuff

"I would not be doing what I love to do without the presence and impact of NASTT. I wanted the industry to know about a record HDD project and NASTT gave me the access and opportunity to tell to the industry."

~ Jim Murphy, UniversalPegasus International

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APRIL 14-18 | PROVIDENCE, RI

NASTT NO-DIG SHOW 2024

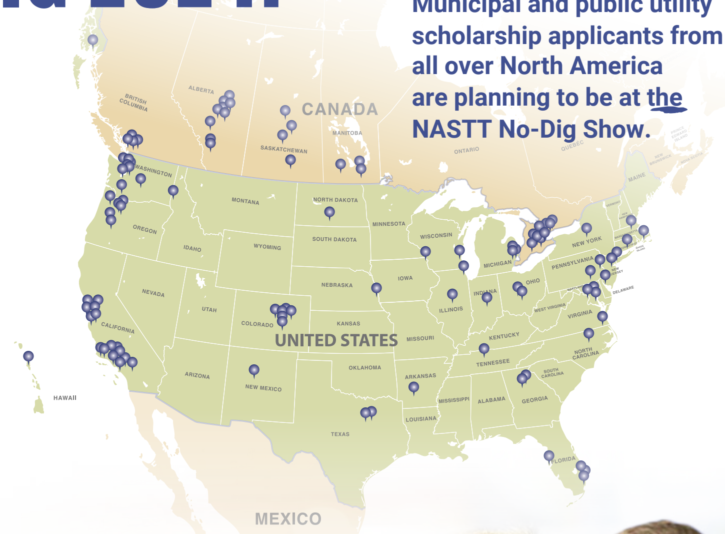
GREEN ABOVE. GREEN BELOW.

NASTT 2024 NO-DIG SHOW | APRIL 14-18 | PROVIDENCE, RI

ATTENTION TRENCHLESS CONTRACTORS....

Municipal & Public Utility Decision Makers will be at NO-DIG 2024!

Doing business with municipal agencies and public utilities is crucial to the trenchless industry. NASTT's Municipal & Public Utility Scholarship brings hundreds of decision maker agency representatives in-person to the No-Dig Show. Since its inception, over 2,000 delegates have been onsite looking for solutions to their infrastructure challenges that you can provide.



Municipal and public utility scholarship applicants from all over North America are planning to be at the NASTT No-Dig Show.

CONNECT WITH THEM AT NO-DIG!

- Networking Events
- Exhibit Hall
- Technical Education Session

Visit nodigshow.com to register!

Register today to secure these future customers!
Join us at the Rhode Island Convention Center, April 14-18.

NASTT 2024 No-Dig Show Scholarships Provided to Municipal & Public Utilities

APRIL 14-18 | PROVIDENCE, RI
NO-DIG SHOW
2024

Municipal and public utility scholarships cover registration and accommodations costs for over 150 delegates attending the 2024 No-Dig Show, April 14 – 18 in Providence, Rhode Island!

In 2013, NASTT established the No-Dig Show Municipal & Public Utility Scholarship Award Program to provide education and training for employees of North American municipalities, government agencies and utility owners who have limited or no training funds due to economic challenges. At least 100 applicants are awarded the scholarship annually, with a total of over 2,000 scholarships since the inception of the program.

Who Do You Want to Meet at No-Dig 2024?

Doing business with municipal agencies and public utilities is crucial to the trenchless industry. NASTT's Municipal & Public Utility Scholarship brings hundreds of decision-maker agency representatives in-person to the No-Dig Show. Nearly 2,000 delegates have been onsite looking for solutions to their infrastructure challenges that you can provide.

Register today to secure these future customers! Join us at the Rhode Island Convention Center, April 14 – 18, 2024. Visit www.nodigshow.com to register today!

"The show provided many opportunities to network with contractors, consultants, and decision makers within municipalities and utilities across the United States and Canada."

– Joseph Barnes, Johnson County Wastewater

"I found the sessions interesting and gained a lot of useful information to bring back to my community. I had such a narrow view of Trenchless Technology before the show, and now see it in a clearer fashion and in a larger light. The exhibits were interesting and I found many products or ideas that directly related to what I deal with on a day to day basis."

– Matt Overeem, Village of Wilmette

Each year NASTT hosts a reception for the Municipal Scholarship recipients to network with each other and kick off the conference

NASTT 2024 NO-DIG SHOW MUNICIPAL & PUBLIC UTILITY SPONSORSHIPS

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Township of Springwater
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Upper Trinity Regional Water District
Village of Wilmette Public Works
WSSC Water
Xcel Energy

Q A with

Kate Wallin

Kate Wallin is a Project Manager at Bennett Trenchless Engineers in Folsom, CA. She has 18 years of experience in trenchless technology and has provided design and construction management services on projects using horizontal directional drilling, microtunneling, pipe ramming, guided boring, and earth pressure balance pipe jacking. Kate is a contributing author on the 5th edition of NASTT's Horizontal Directional Drilling Good Practices Guidelines and Presentation. Kate is the current chair of the NASTT Western Chapter and was honored to receive NASTT's Volunteer of the Year Award in 2023.

BENNETT
trenchless engineers

What first inspired you to become interested in the construction & engineering field, particularly underground construction?

I followed a rather circuitous career path that started in chemistry, made a detour into cooking in restaurant kitchens, and finally landed in trenchless design. I didn't have any engineering or geotechnical experience, but thankfully, my STEM background provided the foundation for learning the fundamentals of trenchless design. I suppose it didn't hurt that I was working at the same company as my husband who could translate for me in the early days! As I learned about the industry, I became interested in the puzzle-solving aspects of trenchless design. It's always satisfying to take a seemingly impossible group of project constraints and devise a creative solution to the problem. My favorite trenchless projects are often very collaborative, not only internally, but also when the design team – owner, prime, geotech, permitting, contractor - works together to identify issues, discuss alternatives, evaluate risk and mitigation measures, and work through construction issues to complete a successful project. Those are also the projects where I get to see the work from other perspectives and gain insight from others' experiences. There is always more to learn!

How did you first get involved with NASTT? What are some of the goals and initiatives you would like to see NASTT pursue?

Bennett Trenchless has always been heavily involved with NASTT and its mission to spread education about trenchless technology. I think I went to my first WESTT regional conference within the first month of joining the firm in 2005; it was like drinking from a fire hose! Since then, my involvement with NASTT grew to authoring NoDig papers, participating in practically every committee, and now finishing my term as Chair of the Western Regional Chapter. I've seen NASTT grow into a much more sophisticated organization that constantly improves the industry.

One thing I'm encouraged to see NASTT pursuing is financial support for experimental research into practical applications. It is often difficult for engineers to gather sufficient data in the field during construction, and the research being done is critical for developing our understanding of the soil and material mechanics that occur underground. Research helps designers mitigate risk and improve the state of practice. As trenchless methods continue to innovate and expand the capabilities of pipeline construction, having a solid research foundation is fundamental to evaluating feasibility and producing designs that can successfully solve difficult challenges.

Is the trenchless industry generally doing a good job of attracting young professionals? What do you think can be done to better engage students and young professionals in the trenchless industry?

The need to recruit quality young engineers has become a critical concern for many trenchless organizations. Many firms in the industry have entry-level positions they are struggling to fill. The biggest hurdle with attracting young professionals to our industry is the limited exposure many undergraduates get to pipeline design, let alone trenchless methods. The universities that have NASTT student chapters are helping to bridge that knowledge gap with specialized courses, guest lectures, site visits, *"I became interested in the puzzle-solving aspects of trenchless design"*

"There is always more to learn! "

and industry networking, but other universities have little, if any, coursework covering trenchless. Unfortunately, the pandemic significantly impacted many of our student chapters by limiting their ability to meet and participate in events like No-Dig that encourage student involvement. In the past several years, NASTT has made great strides in re-engaging the student chapters and bolstering their programs by providing scholarships to attend NoDig, providing research and activity grants, restructuring the Student Research Competition and by facilitating collaboration with industry professionals outside of the university.

Through my experience with the Western Chapter and the NASTT Student Chapter Committee, I've learned that each of our student chapters face unique challenges. Although I think we'd all love to provide each school with a standardized roadmap for developing a strong trenchless educational system, the realities are far more nuanced. Some schools have their trenchless programs based in Construction Management, while others are in the Civil Engineering department, resulting in very different coursework offerings. Some schools provide trenchless courses for undergraduates, while others limit those courses to their graduate programs. In addition, many schools with strong civil programs have numerous student groups competing for their limited free time and engagement.

The key for student chapter success seems to depend on engaged faculty advisors that are supported by other industry professionals. With the relatively rapid turnover of the students through graduation, the advisor is the person who is responsible for maintaining momentum in the chapter. Several of our universities are lucky to have multiple professors engaged in the trenchless industry who can not only provide additional guidance and support for the chapter but can help to drive development of the trenchless curriculum. To encourage the interest of young professionals, the trenchless industry needs to support the efforts at the university level,

"It was like drinking from a fire hose! "

whether that is through guest lecturing, providing lunch-and-learn seminars on trenchless methods (who doesn't love free food?), and most importantly by providing career opportunities in our field. NASTT has gotten the ball rolling on this effort by developing Recruitment Connection Hours at NoDig to exhibit the potential career paths available to young professionals. But I think local involvement by NASTT Regional Chapters will likely have a greater impact, since it is easier to cultivate an interest in the field with frequent, in-person engagement.

Biggest challenges facing the trenchless industry today? Has acceptance and understanding of trenchless technology improved?

The rapid growth of the trenchless market has been a double-edged sword. I am thrilled that utility owners increasingly use trenchless methods to minimize impacts to existing infrastructure and the environment. But I think that trenchless has started to become seen as a magical solution to any difficult project, especially with new installations. The trenchless industry continues to break records with challenging projects, and I think that those projects are now sometimes seen as standard, not as exceptional. The planning, logistics, coordination, experience, and hard work that go into designing and constructing landmark projects seem to be discounted by some owners and engineers.

While the ranks of quality engineering firms with solid trenchless experience and skill continues to grow, more frequently, claims are arising from design-bid-build projects where the designers defer to "contractor means and methods" to figure out challenging constructability issues without adequately identifying at least one specific, constructable solution. Leaving significant design effort and risk to the contractor is unfair in a low-bid environment. Although the initial low price-tag may be attractive to owners, the reality is that the low-bidder may be the one who does not have the experience to incorporate risk mitigation measures, exposing the entire project team to cost overruns, delays, and potentially costly legal action. It is important to emphasize that for these challenging projects to be successful, a more robust level of design that fairly shares risk between the owner and contractor is required.

What do you personally enjoy most about working in the trenchless technology field?

The people in the trenchless community make this a fun industry to work in. Going to industry events always feels like it's half work, half reunion. The networking and collaboration that I have been able to participate in as part of the industry is also very helpful technically. Learning about other projects and how colleauges addressed various challenges always helps me be more thoughtful in my designs. Having a resource of individuals with a wide breadth of knowledge comes in handy when I need a second opinion. It's also nice to collaborate with people who are fun to have a beer with at happy hour, and our industry seems to have no shortage of them!

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Planning Considerations for Performing Large-Diameter Utility HDD Work in Urban Areas

By: Marvin Klein, Vermeer Corporation

Many utilities and municipalities are increasingly choosing trenchless construction over open-cut work in bustling urban areas for the upgrade of water, wastewater, gas, and electrical transmission lines. The general public, not closely associated with the construction industry, dislikes enduring months-long street closures and disruptions due to underground work. This is particularly true for sewer rehabilitation projects where the mess is often unavoidable. Nonetheless, whenever possible, city officials have a marked preference for trenchless methods.

Using horizontal directional drills (HDDs) and auger boring machines to install large-diameter product helps minimize the impact on the people living in the community and the amount of restoration work needed after the utility is in the ground.

While using HDDs and other trenchless equipment in congested city environments is common, when larger machines are brought in to install large-diameter products, many extra factors need to be considered. Space limitation, jobsite logistics, drilling fluid management, noise restrictions and other potential city policies are common obstacles on large-diameter trenchless projects in urban areas.

Large HDD rigs with onboard cab and rod rack are ideal for urban areas with limited space

> *"Whenever possible, city officials have a marked preference for trenchless methods."*

To help mitigate potential issues with projects happening in city limits, it's best to analyze project details during the bid process carefully. Contractors need to study the entry and exit site dimensions to determine if they have enough room for all of the equipment required to do the work. They also need to look into city-specific permitting and restrictions that may impact their work. Occasionally, those details aren't spelled out very well, so asking a lot of questions is important to develop the most accurate estimate for the project and prevent surprises when the work starts.

Space limitations

When working in more congested areas, having enough space for all the machinery needed to execute a large-diameter bore is one of the most important factors to consider ahead of time.

If there isn't enough room, contractors may have to evaluate everything, from using a drill with a smaller footprint to adjusting the way some of the support equipment is used on the project. Maxi rigs that have an onboard cab and 20-foot (6.1-m) rod rack are a good option for these types of projects because they are much more compact than many of the drills used on rural oil and gas projects. However, crews may spend more time making and breaking rod connections, which may add extra time to the job. Also, crews may have to move their

Fluid management is an important consideration

mud recycling systems to a separate location if spacing is too tight. For these reasons, the square footage of the jobsite can have a huge impact on how long a job will take.

On the exit side of the bore, available space will be determined if there is room to lay out piping ahead of pullback or if it will need to be added a section at a time.

Jobsite logistics

The site's specific location is important, too, since there can be less flexibility for setback distances in urban areas.

To maintain the drill pipe and product bend radius, crews may need to make adjustments to the entry angle, which can take a lot of planning and prep work to build up a pad to accommodate the right angle.

The site's location can also impact getting machinery and workers to the job every day and dictate the need for additional crews to do tasks like directing traffic. Contractors need to make sure they understand local street weight limits because they may need to make more trips or obtain special permits to bring the machinery needed for the job. It's better to look into those details ahead of time because extra transport costs and the need for extra workers on a job can have a substantial impact on operational expenses.

Fluid management

From identifying a nearby water source and the closest disposal site, thinking through fluid management is another important consideration that may require more planning on urban jobs.

Space on each end of the bore may determine where a crew can set up a reclaimer. However, whether the fluid is being recycled on the entry or exit side, there needs to be a plan to get it back to the drill. In some cases, it may be able to be pumped back, but if there are above-ground obstacles like roadways or buildings, that's not always possible. In those instances, contractors may need to truck it back and forth.

Contractors may need to establish a separate mud management site when there isn't enough room to reclaim used drilling fluids on either side of the bore. Using vac trucks, crews will bring used slurry to the mud management site to clean it, then use water trucks to bring it to the drill. There are many moving pieces on jobs that require the use of multiple trucks, but sometimes, crews just don't have any other options.

Contractors also need to think through a mud containment plan for urban projects. While it's important to take every step possible to avoid inadvertent returns, crews need to discuss what steps need to be taken in the event that may happen.

Noise limitations

Next, contractors need to investigate any city noise restrictions so they can adjust their operations to work within them or file for a permit if they have to exceed them.

In some cities, HDD crews may have to erect sound barrier walling to minimize sound. In addition to adding extra time and expense to a project, additional equipment may need to be used on the jobsite, like fans to circulate the air within the walled-off area.

City policies

Every city — large or small — has its own unique policies that could present challenges for HDD contractors on more

"Essential to have an ongoing dialog with the utility owner and the inspectors."

prominent bores, so it's essential to have an ongoing dialog with the utility owner and the inspectors assigned to the project.

In addition to noise limits, traffic restrictions, and fluid management guidelines, cities may also have policies that can do everything from limiting a crew's hours of operations to delivering as-built bore profiles for future expansion. Every situation is different, which is why it's so important to try to sort through those details ahead of time.

With so much news being made about the state of the cities across the world's aging infrastructure, there is a strong demand for utility rehabilitation work. Taking the time to understand and navigate through all the additional challenges of doing large-diameter HDD work in more congested areas can help a contractor grow their business and become a trusted partner for utility companies.

Using HDD helps mitigate community impacts

Prior to joining Vermeer Corporation in 1993, ***Marvin Klein*** *worked for an Iowa-based underground utility company as a drilling specialist and equipment coordinator. Since then, he has been dedicated to supporting the Vermeer worldwide dealer network with sales and field support for the company's trenchless product line-up. As an industry veteran, Marvin has also consistently shared his knowledge in promotion of trenchless methods through many presentation and panel appearances. Marvin lives in Pella, Iowa USA with his wife Marcia and enjoys spending time in the outdoors.*

Exciting News:
New NASTT Website Rolled Out in January!

The new NASTT website is LAUNCHED! We took your feedback and developed new tools and features. Further improvements will be rolled out in phases over the next few months.

An Improved Design:

- *New navigation to get you where you're going faster*
- *Pared-down content that's easier to scan*
- ***NASTT information and the No-Dig Show content all on one site!***
- *Calendar view of upcoming training opportunities and events*

Improvements Coming Soon:

- *New and improved Technical Paper Library*
- *Trenchless 101 Knowledge Hub*
- *New Trenchless Video and Photo Library*
- *New accessibility features*
- *Interactive Regional Chapter map*
- *And so much more!*

While we are working hard to ensure a seamless transition, you may encounter pages that are still in the process of being updated. We appreciate your patience and understanding during this exciting time of improvement. Our team is dedicated to making the transition as smooth as possible, and we believe the new features and enhancements will make your online experience even better. If, during your visit, you encounter any difficulty finding the information you're looking for, please don't hesitate to reach out to Jenna Hale, NASTT Marketing Manager, who can help you find what you are looking for on the website.

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All your NASTT information and No-Dig Show content are now consolidated on nastt.org! Experience seamless access to member benefits, conference details, trenchless information, and more, all in one place. The previous No-Dig Show website will redirect you to the main site, making your exploration easier than ever. Visit nastt.org for a comprehensive dive into the world of trenchless technology!

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CUIIC Pipeline Rehabilitation Academy

Discover the Future of Pipeline Rehabilitation at the 2024 Pipeline Rehabilitation Academy in Vancouver

The Canadian Underground Infrastructure Innovation Centre (CUIIC) at the University of Alberta, in collaboration with Benjamin Media and the CUIIC Pipeline Rehabilitation Committee, is pleased to extend an invitation to industry professionals for the 2024 Pipeline Rehabilitation Academy, scheduled for March 13-14, 2024, at the prestigious Fairmont Hotel Vancouver in Vancouver, British Columbia.

Unlocking Insights for Sustainable Pipeline Management
The 2024 Pipeline Rehabilitation Academy is a comprehensive two-day course meticulously crafted to empower attendees with in-depth knowledge in asset management, condition assessment, maintenance, and rehabilitation of underground pipelines. Participants will have the opportunity to earn Continuing Education Units (CEUs) from the Engineering Institute of Canada while immersing themselves in the latest advancements and cutting-edge technologies aimed at repairing and revitalizing aging infrastructure.

Key Highlights of the Academy:
- Full access to presentations, breakfast, lunch, coffee breaks, and Networking Reception on March 13th
- CEUs from the Engineering Institute of Canada (available upon request)
- Municipal Discounts and CUIIC Member Rates
- Register 4+ attendees from the same company and save 10 percent (Enter Code: CUIICPIPE10)
- Exclusive hotel discount at the Fairmont Hotel Vancouver
- Student Scholarship opportunities available

Join Us for a Transformative Experience
We extend a warm invitation to industry professionals and organizations to join us this March in Vancouver. Engage with top-notch industry professionals, gain valuable insights, and foster meaningful connections with peers. Register now for an enriching experience at the forefront of pipeline rehabilitation.

For more information, please visit
academy.cuiic.ca/pipeline-rehabilitation

About CUIIC:
The Canadian Underground Infrastructure Innovation Centre (CUIIC) is a research and education centre focused on important issues of underground infrastructure. CUIIC is located at the University of Alberta in Edmonton.

CUIIC focuses on providing stakeholders across all sectors with opportunities to collaborate on research and training opportunities in underground infrastructure. Together, we foster innovation to provide cost-effective, sustainable solutions to the challenges involved in building, assessing, and rehabilitating underground infrastructure.

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New generation trailer vac for utility work

Vermeer has introduced the first model of its next generation of new trailer vacuum excavators, the Vermeer VX75. It is the most powerful Vermeer vacuum excavator in the 75-hp class, equipped with a 1,500-cfm (42.5-m3/min) vacuum blower capable of generating 15 in Hg (381 mm Hg) of suction force. It is available with a 5-in (12.7-cm) hydraulic boom option for standard units and a 4-in (10.2-cm) hydraulic boom option for air and jetter versions.

The VX75 is designed for challenging utility work, including potholing, horizontal directional drilling (HDD) slurry management, and microtrenching dust containment.

"The new VX75 vacuum excavator combines all of the best qualities of the prior McLaughlin and Vac-Tron product lines, as well as many more improvements to create a new generation of Vermeer vacuum excavators," said T.J. Steele, product manager for Vermeer MV Solutions. "In addition to all of the performance-enhancing features that are sure to get contractors' attention right away, we also designed this unit to be lightweight, incorporated a CAN bus control system throughout to simplify wiring and improve reliability, delivered operator-friendly controls, and provided more machine operating information."

The VX75 vacuum excavator's control panel and full-function remote control allow operators to start and stop the machine and control everything from the boom to the water system and spoil tank. This remote control feature is especially useful for contractors using the excavator for slurry management, as they no longer have to manually restart the unit when draining a pit, potentially saving time and fuel.

Powered by a 74.3-hp (56-kW) Kubota diesel engine, the VX75 can be equipped with either a 500-gal (1893.7-L) spoil tank with two 125-gal (473-L) freshwater tanks or an 800-gal (3028-L) spoil tank with two 205-gal (776.5-L) freshwater tanks. It also has an 8-gpm (30.3-L/min), 3,000-psi (206.8 bar) water system, a dual cyclone filtration system, and a full open cam over the spoil tank door.

The VX75 can be configured with a 180-cfm,110-psi (5.1 m3/m, 7.58 bar) air compressor for dry digging and powering pneumatic tools, an 18-gpm at 2,000-psi (68.1 L/min at 138 bar) jetter for cleaning pipes and culverts up to 12 in (30.2 cm) in diameter, and an 8-gpm (30.3-L/min) auxiliary hydraulic system for powering tools such as core saws. Other optional accessories available on the VX75 include a strong arm, an arrow board, a 300,000 BTU hot box, and an external kerosene tank for the hot box.

For more information about the Vermeer VX75 Vacuum Excavator, contact your local Vermeer dealer or visit www.vermeer.com.

Wyo-Ben, Inc. Announces Acquisition of Bentonite Operation of M-I Swaco

Wyo-Ben, Inc., a leading provider of high-quality drilling fluids and minerals, is excited to announce its recent acquisition of the bentonite operation of M-I Swaco, a division of Schlumberger and renowned global leader in drilling fluid systems and services. This strategic move further solidifies Wyo-Ben's position as a leader in the industry and opens up new avenues for growth and innovation.

The acquisition of M-I Swaco bentonite operation located in Greybull, WY, represents a significant milestone for Wyo-Ben, as it brings together two industry powerhouses with complementary strengths and expertise. By combining resources, knowledge, and experience, the newly formed entity will offer an enhanced portfolio of products and services to customers worldwide.

Wyo-Ben has built a strong reputation over the years for its commitment to delivering superior drilling fluids, sealants, and additives that meet the unique needs of its customers. This addition will further enhance Wyo-Ben's ability to provide tailored solutions for drilling and completion challenges across a wide range of applications.

M-I Swaco's established global presence and extensive customer base will also contribute to the accelerated growth and market expansion of Wyo-Ben. The acquisition will bolster the company's ability to serve its customers on a larger scale, tapping into new markets and providing a broader range of integrated solutions to address the evolving demands of the industry.

"We are thrilled to announce the acquisition of the bentonite operations known as M-I Swaco," said David Brown, CEO of Wyo-Ben. "This acquisition aligns perfectly with our long-term growth strategy and allows us to provide an even more comprehensive suite of products and services to our valued customers worldwide. By combining our strengths, we will enhance our capabilities and unlock new opportunities for innovation and success. We warmly welcome the employees at M-I Swaco into the Wyo-Ben family."

Both Wyo-Ben and M-I Swaco share a common commitment to excellence, quality, and customer satisfaction. The acquisition will facilitate the exchange of best practices, technical expertise, and operational efficiencies, resulting in improved customer experiences and accelerated innovation.

The transition process will be carried out meticulously, ensuring a seamless integration of operations and minimal disruption to existing customers. Wyo-Ben remains committed to maintaining the highest level of service and support during this transition period.

This acquisition is a clear demonstration of its dedication to driving industry advancement and maintaining its position as a trusted partner for markets we serve. The combined strengths of these two industry leaders will undoubtedly lead to enhanced value creation for customers and shareholders alike.

ARA
American Rental Association

ARA's Quarterly Forecast Shows Increased Optimism, Slower Growth And Resilient Markets

Rental revenue projections increase in U.S. and Canada heading into 2024

In its updated forecast, the American Rental Association (ARA) indicates that United States equipment rental industry's growth will soften but still grow. Last quarter, the year-over-year growth was expected to be 7.6 percent in 2023 and 3.1% in 2024. The most current projections indicate 11.8 percent growth in 2023 totaling $71.5 billion in construction and general tool rental revenue. As for 2024, a 7.1% revenue increase is now expected. This forecast includes both traditional and specialty as the new industry measure. Last quarter the association corrected the forecast that underestimated non-residential construction spending by at least 20 percent and 'specialty rental' in overall rental revenues.

"We are more bullish this quarter than last quarter," says Scott Hazelton, managing director at S&P Global. "We are seeing a decent uptick with inflation moderating and our projections are relatively similar — stagnant but strong. It's important to note that there will be more growth in construction and industrial equipment (CIE) than in general tool."

Earlier in the year, the forecast predicted a recession that did not materialize. While the first two quarters of the year proved slow, third quarter revenues are very strong, and the quarter four projections appear that way as well.

"The biggest change is in the general tool revenue projection," Hazelton says. "This is probably a function of timing with manufacturing strikes and that the housing market has been more resilient than we thought it would be. People are renovating homes because they are staying in them and home values are trending upwards so there is incentive to invest in their homes."

Canadian equipment rental revenue growth is higher in 2023 compared to last quarter's projections due to inflation and resilient demand.

The CIE outlook in Canada is slower growth with strong levels of activity in 2024, that is a 3.7 percent revenue increase, making it a $4.5 billion industry with stronger growth anticipated in outbound years, a 7.2 percent revenue increase in 2025 and 5.7 percent in 2026.

There are some very real issues with Canada's housing market and that is the primary cause of the revenue decline in 2023, totaling $971 million. In 2024, the projected general tool revenue will total $963 million, a 0.9 percent decline from 2023.

ARA's quarterly member survey showed conflicting results amongst members with half of respondents saying they expect to see a revenue increase in quarter four and half expecting a revenue decrease.

This quarter there was also an increase in members who believe the situation for business is more stagnant.

For more in-depth economic data, visit **www.ARArental.org/ara-rentalytics**, to learn more about Rentalytics™.

About ARA: (www.ARArental.org) The American Rental Association, Moline, Ill., is an international trade association for owners of equipment and event rental businesses and the manufacturers and suppliers of construction/industrial, general tool, and event rental equipment. ARA members, which include more than 12,000 rental businesses and more than 1,000 manufacturers and suppliers, are located in every U.S. state, every Canadian province, and more than 40 countries worldwide. Founded in 1955, ARA is the source for information, advocacy, education, networking, and marketplace opportunities for the equipment and event rental industry throughout the world.

North American Society for Trenchless Technology (NASTT)
NASTT's 2023 No-Dig North Show

Edmonton, AB
October 23-25, 2023

WA-T1-04

Live Sliplining in Surrey

David O'Sullivan, PW Trenchless Construction Inc, Surrey, British Columbia
Tonia Jurbin, P. Eng. (retired) Writer & Editor, Greater Vancouver, British Columbia

1. ABSTRACT

Metro Vancouver (MV) is a regional district in the western province of British Columbia, Canada that serves 21 municipalities and one Treaty First Nation with a population of about 2.7 million. MV owns and operates 530km of sanitary sewers ranging in size from 200mm to 3,000mm, which only accounts for about 10% of all the municipal sanitary pipes in the region. Condition assessments using video inspections are carried out a rate of 5% per year which may not sound ambitious, at a cost upwards of $25,000 to inspect and interpret small sections of pipe it is a long-term program. Smaller immediate-needs issues are dealt with as maintenance items, larger issues and upsizing projects are capitalized.

Typical rehabilitation methodologies involve bypassing a sewer to allow the process to be completed. Live flow sliplining allows the sewer to continue to function within the existing pipe during the rehabilitation work. This process substantially lowers the risk of spills and eliminates the significant costs associated with bypassing a trunk sewer which can be up to 70% of the project costs depending on location, environmental and social setting, duration of the bypass, pipe size, and whether the pipe is gravity or pressure. Regardless of the specifics, bypassing will always add risk and cost to the project.

Download the full paper from the following link:

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North American Society for Trenchless Technology (NASTT)
NASTT's 2023 No-Dig North Show

Edmonton, AB
October 23-25, 2023

WM-T1-01

Case Study on the Installation of a Large-Diameter Crossing Using Pilot Tube Guided Auger Boring and Pipe Ramming Techniques

Heather Hughes-Adams, Delve Underground, Vancouver, BC
Michelle van der Pouw Kraan, Delve Underground, Vancouver, BC
Isabelle Weber-Concannon, Metro Vancouver Projects, Vancouver, BC
Norman Joyal, Delve Underground, Walnut Creek, CA
Wolfe Lang, Delve Underground, Portland, OR

1. ABSTRACT

Metro Vancouver's Fraser River Crossing Project involves installing two new sewer forcemains under the Fraser River. These 914 mm diameter (36 in.) pipes will carry wastewater from Maple Ridge and Pitt Meadows to the future expanded and upgraded Northwest Langley Wastewater Treatment Plant. The new pipes will increase the capacity of the existing system to help ensure the continued reliable and safe management of sewage in a growing region and provide improved seismic resiliency. The project includes a 127 m (417 ft) long trenchless crossing beneath the Golden Ears Bridge on- and off-ramps, approximately 600 m (1,968 ft) of open-cut forcemain, and twin 1,600 m (5,249 ft) long horizontal directional drilling (HDD) installations under the Fraser River. The general contractor for the project is Pomerleau.

The trenchless crossing beneath the Golden Ears Bridge on- and off-ramps consists of a 2.1 m (6.9 ft) diameter steel

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North American Society for Trenchless Technology (NASTT)
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Edmonton, AB
October 23-25, 2023

WM-T3-04

Condition Assessment and Rehabilitation Planning for an 1800 mm Diameter Pump Station Suction Header in Ottawa, ON

James Fookes, P.Eng, Morrison Hershfield Limited, Ottawa, Ontario
Adam Braun, P.Eng., Morrison Hershfield Limited, Winnipeg, Manitoba
Bryan Kipp, P.Eng., Morrison Hershfield Limited, Ottawa, Ontario

1. ABSTRACT

The City of Ottawa's main purification plant at Lemieux Island has been in service since 1931. The plant's high lift pump station was constructed within an earlier raw water pumping station, with the suction header encased in concrete within the former river intake gallery below the pumping station floor. Constructed from lap welded steel pipe with riveted flanges and required to be near-continuously available for operation, this critical asset has long posed significant logistical challenges to inspection and even greater challenges to rehabilitation.

Following the only known inspection of the suction header in the 1990's and a failure in 2017, the City was keen to understand more about the condition of this critical infrastructure and review rehabilitation options to ensure its long-term operation. This paper will discuss the logistical and technical challenges of completing an inspection and condition assessment of the pipe, the rehabilitation approaches considered, and lessons learned during the eventual successful work. Rehabilitation planning had to consider the structural needs of the pipe itself, available technologies,

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TA-T4-01

Rehabilitation of the Webbwood Drive Horseshoe-Shaped Storm Sewer in Sudbury Ontario

David Crowder, R.V. Anderson Associates Limited, Toronto, Ontario
Josée Boudreau, R.V. Anderson Associates Limited, Toronto, Ontario
Andrew Peltomaki, City of Greater Sudbury, Sudbury, Ontario

1. ABSTRACT

The City of Greater Sudbury (City) owns, operates, and maintains a network of aging large diameter storm sewers with zero tolerance of failure. Detailed and accurate CCTV, and person entry inspections are essential for the effective management and maintenance of the existing sewer infrastructure.

The City retained R.V. Anderson Associates Limited (RVA) to carry out a person entry inspection into the 103-year-old Webbwood Storm Sewer in August 2019.

The Webbwood Storm Sewer was constructed circa 1920 of cast-in place concrete work using opencut construction methods. The arched shaped concrete sewer ranges in size from (1.7m high x 1.50m wide) to (1.80m high x 1.76m

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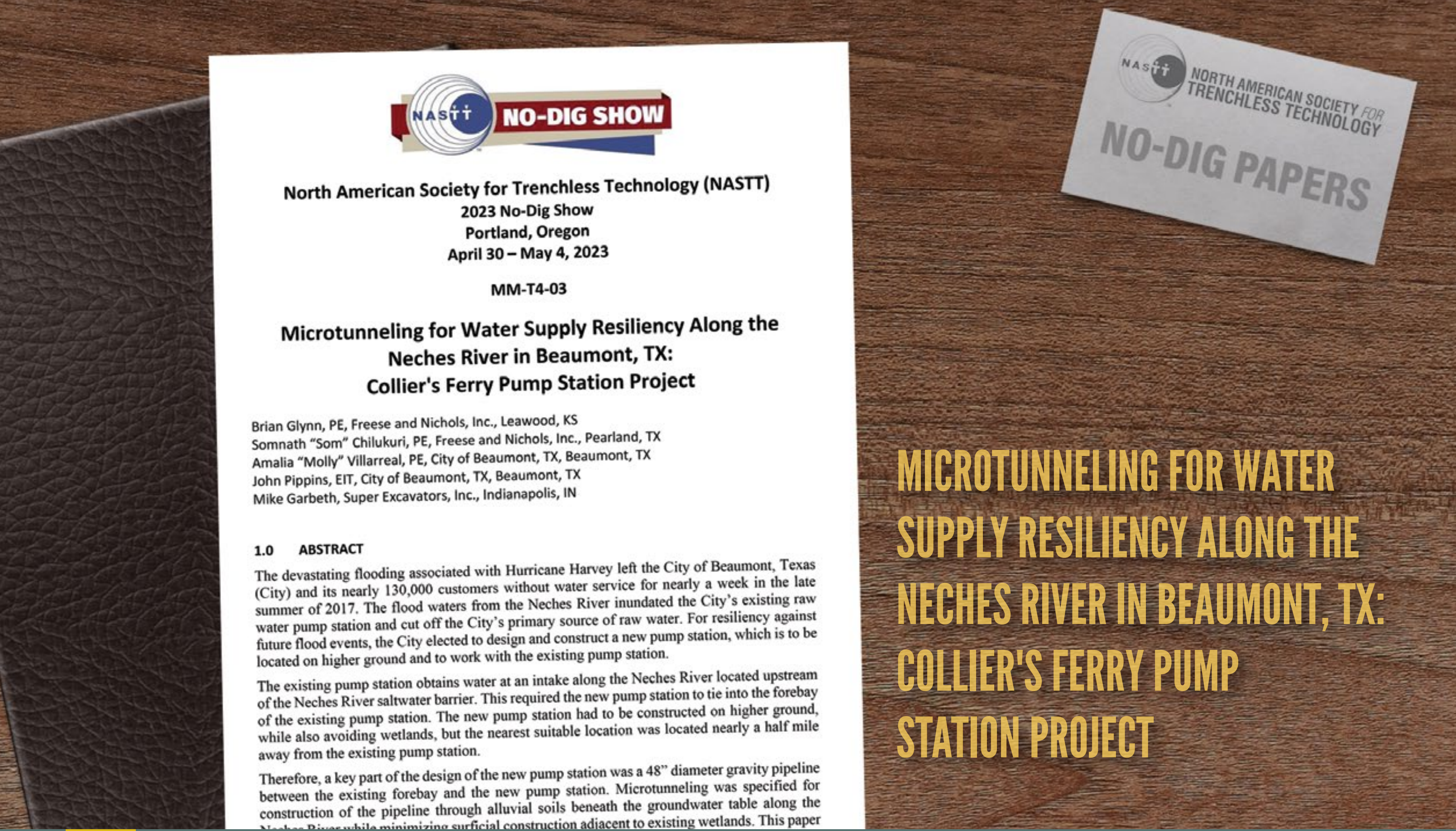
NO-DIG SHOW

North American Society for Trenchless Technology (NASTT)
2023 No-Dig Show
Portland, Oregon
April 30 – May 4, 2023

MM-T4-03

Microtunneling for Water Supply Resiliency Along the Neches River in Beaumont, TX: Collier's Ferry Pump Station Project

Brian Glynn, PE, Freese and Nichols, Inc., Leawood, KS
Somnath "Som" Chilukuri, PE, Freese and Nichols, Inc., Pearland, TX
Amalia "Molly" Villarreal, PE, City of Beaumont, TX, Beaumont, TX
John Pippins, EIT, City of Beaumont, TX, Beaumont, TX
Mike Garbeth, Super Excavators, Inc., Indianapolis, IN

1.0 ABSTRACT

The devastating flooding associated with Hurricane Harvey left the City of Beaumont, Texas (City) and its nearly 130,000 customers without water service for nearly a week in the late summer of 2017. The flood waters from the Neches River inundated the City's existing raw water pump station and cut off the City's primary source of raw water. For resiliency against future flood events, the City elected to design and construct a new pump station, which is to be located on higher ground and to work with the existing pump station.

The existing pump station obtains water at an intake along the Neches River located upstream of the Neches River saltwater barrier. This required the new pump station to tie into the forebay of the existing pump station. The new pump station had to be constructed on higher ground, while also avoiding wetlands, but the nearest suitable location was located nearly a half mile away from the existing pump station.

Therefore, a key part of the design of the new pump station was a 48" diameter gravity pipeline between the existing forebay and the new pump station. Microtunneling was specified for construction of the pipeline through alluvial soils beneath the groundwater table along the Neches River while minimizing surficial construction adjacent to existing wetlands. This paper

MICROTUNNELING FOR WATER SUPPLY RESILIENCY ALONG THE NECHES RIVER IN BEAUMONT, TX: COLLIER'S FERRY PUMP STATION PROJECT

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This paper was selected as one of the more notable papers (New Installations) from all the presentations at the 2023 NASTT No-Dig Show in Portland OR. NASTT No-Dig Papers are available for download, free to members, at www.nastt.org

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2. INTRODUCTION

The Water and Sewer Services Department of the City of Beaumont, Texas (City) provides water to nearly 130,000 residents. The City's primary source of water are two intakes upstream of the saltwater barrier along the Neches River. From these intakes, the raw water is conveyed by gravity along the Neches River and siphons under the Neches River to the forebay of the Lawson Raw Water Pump Station located adjacent to the Neches River, which pumps the raw water to the City's Water Treatment Plant, see Figure 1. The City's water supply is supplemented with groundwater wells located north of the City.

Figure 1. Map of City's Raw Water Infrastructure

In late August 2017, the existing Lawson Raw Water Pump Station was inundated by floodwaters from the Neches River due to Hurricane Harvey and was only accessible by boat for several days as the access road leading to the pump station was submerged by 10 to 15 feet of water, see Figure 2 and 3. The floodwaters shutdown the Lawson Raw Water Pump Station as well as the pumps associated with the City's supplemental groundwater wells, leaving the City without water for nearly a week until the floodwaters receded and temporary emergency pumps and pipelines could be installed, while the necessary repairs could be made.

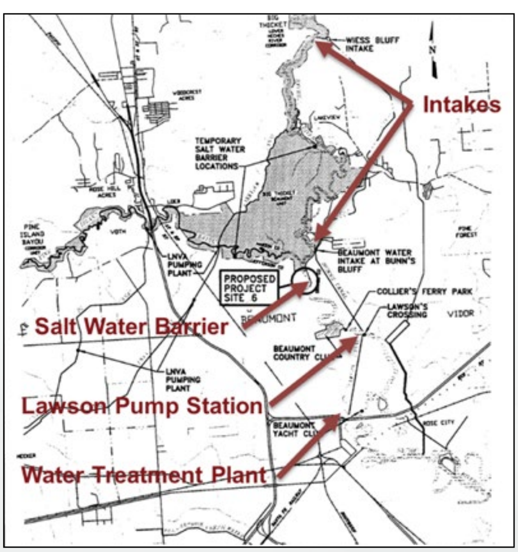

Figure 2. Aerial Photos of the Lawson Raw Water Pump Station Before and During Flooding from Hurricane Harvey

In the aftermath of Hurricane Harvey, the City chose to replace and relocate their primary raw water pump station to higher ground for resiliency and reliability for future storm events. The new raw water pump station is rated for 45 MGD, to provide redundancy and to match the City's current treatment capacity.

3. SITING FOR NEW RAW WATER PUMP STATION

The existing Lawson Raw Water Pump Station is located in a narrow strip of land betweenriverine wetlands along the Neches River and forested wetlands adjacent to the Neches River. The nearest available sites that were located on higher ground outside of the flood plain and suitable to construct a new pump station upon were at least a half mile away from the existing pump station site, see Figure 3.

To minimize the potential impacts to wetlands and associated permitting requirements and modifications to the existing raw water infrastructure upstream of the existing pump station, a pipeline was elected to be designed and constructed along the southern bank of the Neches River between the existing forebay of the existing raw water pump station and the wet well associated with the new raw water pump station. This pipeline would also have to be constructed while the existing pump station remained operational. Site 1 was selected as the location for the location of the new raw water pump

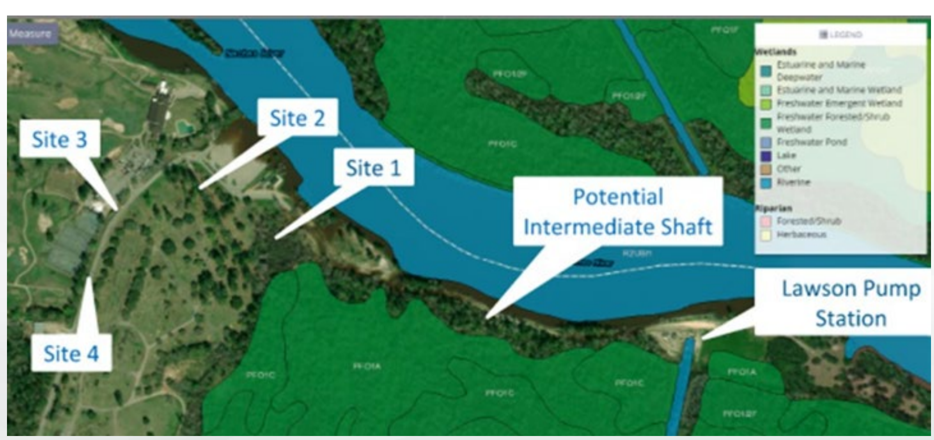

Figure 3. Potential Sites for New Raw Water Pump Station

station (Colliers' Ferry Pump Station) as it minimized the length of conveyance between the existing and new pump stations, while still being located on higher ground and accessible in the event of flooding.

4. PIPELINE FOR NEW RAW WATER PUMP STATION

A 48-inch diameter pipeline, approximately 2,500 feet in length was needed between the existing and new pump stations. In order for the pipeline to operate by gravity, the pipeline would have to tie into the invert of the existing forebay of the existing pump station, which is at approximately elevation -10 feet and the pipeline would then continue at a minimal slope to the location of the new pump station and terminate at an approximate elevation of -19 feet.

Data from thirteen (13) borings associated with the site-specific geotechnical investigation were used to characterize the ground conditions along the pipeline alignment. The ground consisted of cohesionless soils intermixed with cohesive soils (see Figure 4), including poorly graded sands (SP), poorly graded sand with silt (SP-SM), clayey sand (SC), lean clays (CL), fat clays (CH) and organic clays (OH) in accordance with ASTM D2487. The shallow groundwater conditions, proximity to the Neches River, and the likely direct hydraulic connection of the sandy soils between the river and the proposed excavation led to the determination that open cut construction was infeasible for construction of the pipeline.

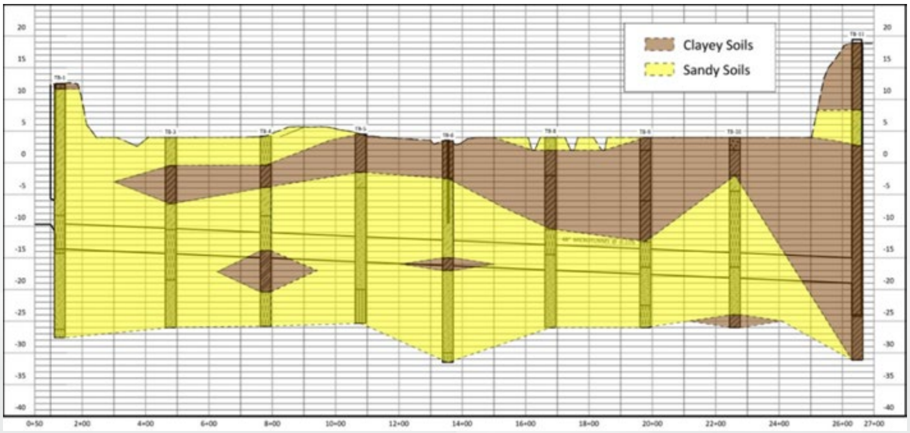

Figure 4. Profile View of Pipeline Alignment with Overlay of General Soil Conditions

5. SELECTION OF TRENCHLESS CONSTRUCTION METHODS

Trenchless construction methods were evaluated during design, including microtunneling, horizontal directional drilling, and Direct Pipe®. While both horizontal directional drilling and Direct Pipe® were technically feasible methods to construct the project, both had similar drawbacks that there was limited working area at the project site for equipment, insufficient area for stringing of pipe, and would require the pipeline to operate as a gravity siphon. Microtunneling did not have the drawbacks of those associated with horizontal directional drilling and Direct Pipe®. Microtunneling was selected in the design as it requires the least working area for the associated equipment and was least likely to impact the wetlands adjacent to the project.

The microtunnel boring machine (MTBM) and pipe jacking equipment were required by the contract documents to be in accordance with the following requirements:

1. Performed in general accordance with ASCE/CI Standard 36-15.
2. Remotely operated and monitored continuously by an operator.
3. Laser guided with a light sensitive or electronic target.
4. Closed and pressurized face machine.
5. Designed and built (or rebuilt) by a recognized, experienced MTBM manufacturer.
6. Capable of handling all loads and conditions presented in the geotechnical reports.
7. Capable of fully supporting the face during both excavation and shutdown periods.
8. Capable of exerting a controllable, measurable, continuous stabilizing pressure at the face to prevent loss of ground, groundwater inflows, and settlement or heave.
9. Slurry type MTBM with pumps or air chambers to provide a pressurized mixture of excavated ground and slurry that balances the ground and groundwater pressures to an accuracy of one foot of equivalent hydrostatic pressure.
10. Utilize a slurry transportation system that is synchronized with the advance rate of the MTBM to avoid excavation and that is capable of bypassing the cutterhead and changing direction of flow to flush or clear any debris.
11. Include an articulated shield that is steerable in all directions to maintain line and grade.
12. Cutterhead shall be reversible drive system so that it can rotate in either direction to minimize rotation or roll of the MTBM and/or jacking pipe.
13. Main jacks shall be mounted within a jacking frame and located in the jacking shaft.
14. Jacking system shall have a rated capacity of at least 25 percent greater than the maximum allowable jacking force determined by the contractor, but shall not exceed the maximum allowable jacking force.

Figure 5. Akkerman SL60 MTBM

15. Maintain at least one intermediate jacking station on site that is available for use in the event that jacking forces reach 80 percent or greater of the maximum allowable jacking force.
16. Incorporate entry and exit seals that into the shaft excavation to maintain watertightness.
17. Perform geotechnical instrumentation monitoring during microtunneling.

The Contractor selected an Akkerman SL60, a slurry type microtunnel boring machine (MTBM), see Figure 5, an Akkerman MT875K jacking frame, which had a thrust capacity of 800 tons, and an Akkerman AZ100 Total Guidance System in order to perform the required microtunneling and pipe jacking.

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Figure 6. RCP Jacking Pipe

6. SELECTION OF JACKING PIPE

Microtunneling required use of jacking pipe in order to construct the pipeline. The contract documents required the contractor to design the 48-inch jacking pipe based on the design criteria listed in the contract documents, which included the following:

1. Fiberglass reinforced pipe (FRP)
   a. Manufactured and tested in accordance with ASTM D3262 for Type 1, Liner 1 or 2, Grade 1 or 3.
   b. Joints incorporate flush fiberglass sleeve couplings or flush bell-spigot joints that utilize elastomeric gaskets made of EPDM. Joints must meet the performance requirements of ASTM D4161.
   c. Minimum pipe stiffness of 72 psi (SN 72) per ASTM D2412.
2. Reinforced concrete pipe (RCP).
   a. Manufactured and tested in accordance with ASCE 27-17 and ASTM C76.
   b. Joints shall be Type C Joints per ASCE 27-17 that are designed for installation by microtunneling or pipe jacking and include a steel bell end or steel joint rings to compress a gasket that forms a watertight seal.
   c. Gaskets shall meet the requirements of ASTM C361, Section 6.9, standard gasket.
   d. Minimum compressive strength of 6,000 psi.
3. Meeting the minimum dimensions on the drawings and capable of handling all loads and conditions presented, including earth load, groundwater load, live load, construction surcharge load, and intermittent hydrostatic pressure load.
4. Incorporate grout ports to allow for lubrication during microtunneling as well as the performance of contact grouting.

Figure 7. Photo of Active Excavation within Secant Piles at Future Location of the Wet Well for the Collier's Ferry Raw Water Pump Station

The contractor selected RCP as manufactured by Rinker Materials as their preferred pipe material, see Figure 6, given their recent experience with the same pipe material, at the same diameter, using the same installation method, and from the same pipe manufacturer from a recently completed project in the vicinity.

7. SHAFT EXCAVATION AND CONSTRUCTION

Shafts were required in order to facilitate microtunnel construction as well as to construct the new wet well shaft associated with the new Collier's Ferry Raw Water Pump Station. Again, given the ground and groundwater conditions, water-tight shaft excavation methods were required. The contract documents required the contractor to design the shaft excavation support and allowed for the following types of watertight shaft excavation support: secant piles, slurry walls, and/or steel sheet piles. The shaft excavation support would also require a watertight working slab at the bottom of each shaft as well as break-in and break-out seals in the walls of the shaft to maintain watertightness for subsequent construction operations. The contractor selected to utilize secant piles for construction of all of the shafts associated with the project, see Figure 7, 8, and 9. Space was limited at the intermediate shaft due to the surrounding wetlands, see Figure 8. Space was also limited for the shaft at the existing Lawson Raw Water Pump Station, see Figure 9, which had to remain operation during the project.

Figure 8. Photo of Shaft and Limited Working Area at the Intermediate Shaft

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Figure 9. Photo of Shaft and Limited Working Area at the Existing Lawson Raw Water Pump Station

8. PROJECT COMPONENTS

In all, the project included the following components contained in a single bid package:

1. Site work, including clearing and grubbing, earthwork, fencing, gravel and asphalt access road.

2. Structural concrete work, including wet well, electrical building, and various concrete slabs and pipe supports.

3. Process mechanical work, including four submersible pumps, associated piping, valves, and fittings, wet well hatches, sluice gates, piping, yard piping, flow meter, and pipe supports.

4. Electrical work, including a 1500kW generator, transfer switch, variable frequency drives, lightning protection, instrumentation and controls, and site lighting.

5. Mechanical work, including four wall pack HVAC units for the electrical building.

6. Microtunneling, including approximately 2,500 feet of 48-inch diameter pipeline.

The contract documents included a Geotechnical Data Report and Geotechnical Baseline Report, which were applicable to the microtunnel and shaft excavation portion of the project only.

9. PROJECT BID RESULTS

Bids for the project were opened on March 24, 2022. The bids for the complete project ranged from $24.9 million to $36.2 million. The engineer's estimate prepared by Freese and Nichols, Inc. was $25.3 million. On April 20, 2022, the City awarded the contract to Allco, LLC for their bid of $24.9 million. Allco, LLC subsequently awarded a subcontract to Super Excavators, Inc. to perform the microtunneling and associated shaft excavation for the project.

10. CONSTRUCTION

The size of the shaft excavation at the Collier's Ferry Raw Water Pump Station was governed by the proposed size of the wet well, which required an excavated diameter of 40 feet at a depth of approximately 50 feet. The size shaft at the Lawson Raw Water Pump Station was governed by the MTBM and associated pipe jacking operation, which required an excavated diameter of 24 feet at a depth of approximately 26 feet. The size of the intermediate shaft was governed by the space needed to retrieve the MTBM from two nearly opposite directions, which required an excavated diameter of 18 feet at a depth of approximately 20 feet. The secant piles were 38 inches in diameter and generally extended 10 feet beyond the depths stated above. Secant pile installation was performed using a Soilmec SR90 hydraulic rotary drill rig. Shaft excavation was performed with track excavators along with cranes and muck boxes at the deeper depths. Secant pile installation and shaft excavation occurred from September 2022 to December 2022 for the three shafts.

The MTBM was setup for the first drive from the shaft at the Collier's Ferry Raw Water Pump Station to the intermediate shaft, a distance of approximately 1,250 feet. The first microtunneling drive was performed between January 6, 2023 and January 20, 2023, and was performed in two shifts, averaging approximately 83 feet per day or 42 feet per shift. The MTBM was setup for the second drive from the shaft at the existing Lawson Raw Water Pump Station to the intermediate shaft, a distance of approximately 1,180 feet. Microtunneling for the second drive was performed between February 28, 2023 and March 10, 2023, again in two shifts, averaging approximately 107 feet per day or 54 feet per shift. The second drive encountered soils with a higher sand content than the first drive and thereby experienced higher advance rates.

11. CONCLUSIONS

At the time that this paper submitted on March 13, 2023, shaft and microtunnel construction was nearly complete with the exception of contact grouting and installation of manholes and piping at the ends of the microtunnel drives. Construction of the Collier's Ferry Raw Water Pump Station is underway, with the concrete lining of the wet well underway as of March 2023.
It is currently anticipated that startup of the new Collier's Raw Water Pump Station will occur in fall 2024.

12. REFERENCES

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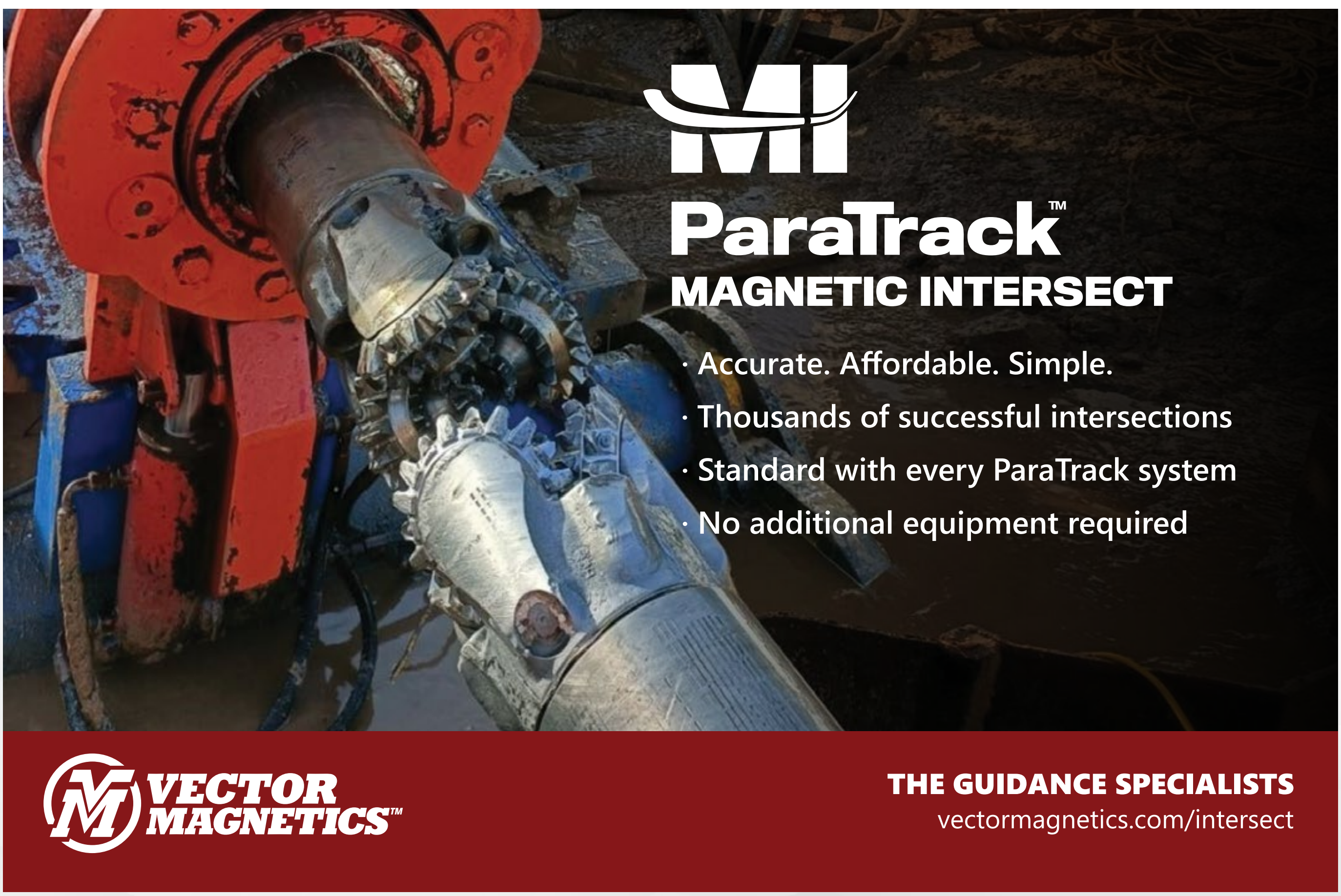

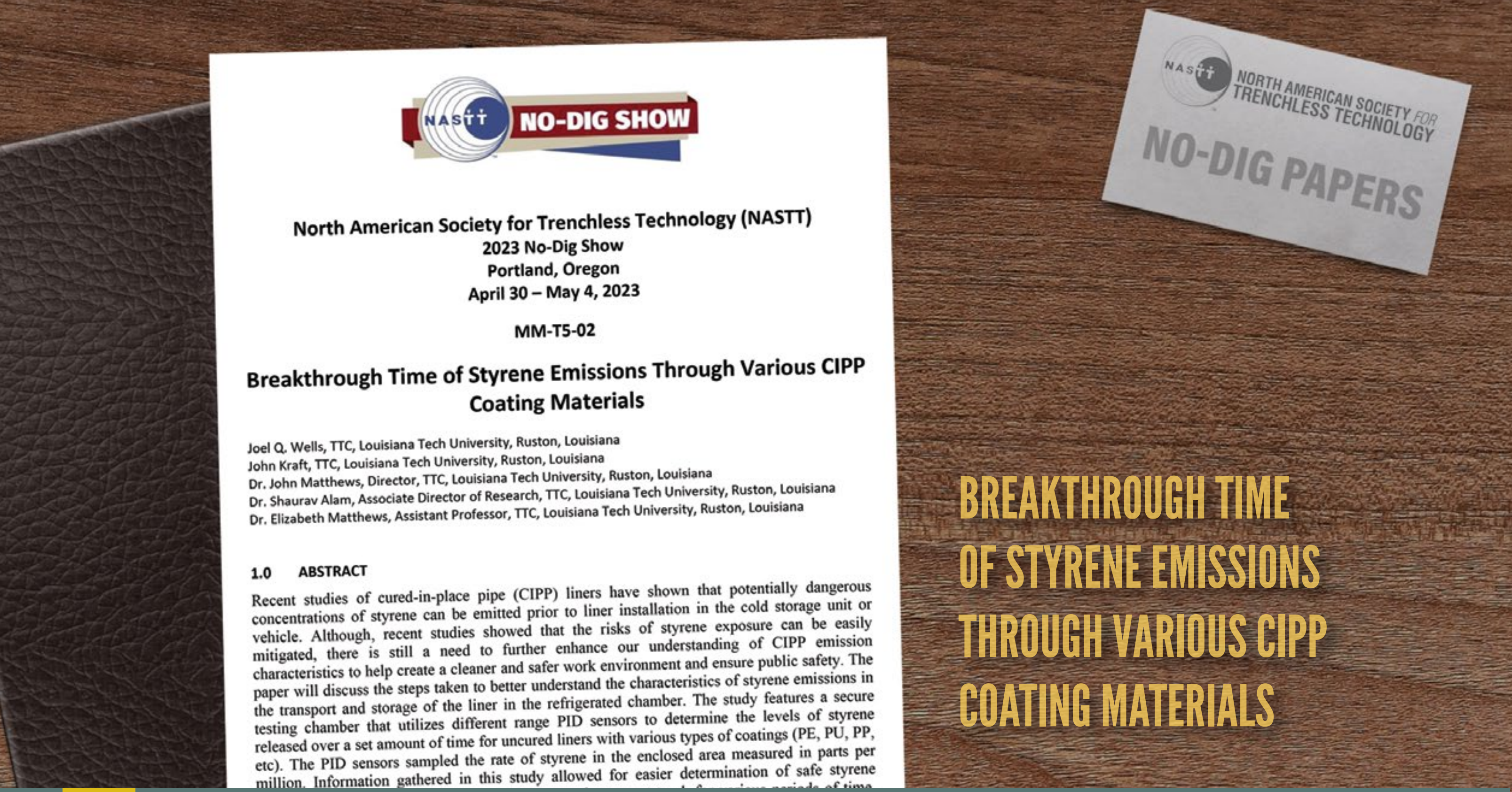

BREAKTHROUGH TIME OF STYRENE EMISSIONS THROUGH VARIOUS CIPP COATING MATERIALS

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1. ABSTRACT

Recent studies of cured-in-place pipe (CIPP) liners have shown that potentially dangerous concentrations of styrene can be emitted prior to liner installation in the cold storage unit or vehicle. Although, recent studies showed that the risks of styrene exposure can be easily mitigated, there is still a need to further enhance our understanding of CIPP emission characteristics to help create a cleaner and safer work environment and ensure public safety. The paper will discuss the steps taken to better understand the characteristics of styrene emissions in the transport and storage of the liner in the refrigerated chamber. The study features a secure testing chamber that utilizes different range PID sensors to determine the levels of styrene released over a set amount of time for uncured liners with various types of coatings (PE, PU, PP, etc). The PID sensors sampled the rate of styrene in the enclosed area measured in parts per million. Information gathered in this study allowed for easier determination of safe styrene emission levels after being held in the refrigerated transport truck for various periods of time. Finally, field validation was performed using an actual transport truck containing various CIPP liners.

This paper was selected as one of the more notable Papers (Rehabilitation) from all the presentations at the 2023 NASTT No-Dig Show in Portland OR, and is an important research study. NASTT No-Dig Papers are available for download, free to members, at www.nastt.org

2. INTRODUCTION

The Trenchless Technology Center has set out to further the understanding of CIPP emission characteristics to ensure crew safety and environmental improvements. Two studies, a lab and field study, have been conducted pertaining to the uncured liner transport truck. Previous studies show that there might be a danger to crew members working in and around the truck due to the dispersion of styrene emission from the liners. The comparison of lab data to field data will be made to determine if the emission levels are deemed safe or if further mitigations are to be made.

3. OBJECTIVES

The goal of this study is to further our knowledge and understanding of CIPP emissions characteristic. Furthermore, we hope to create a cleaner and safer environment for employees and the public. The goals set forth were accomplished through the following objectives:

1. **Study 1 – Lab Scale Study**
   The lab scale portion of the test features a secure enclosed testing chamber that represents the refrigerated truck that liners are transported on to job sites. Several PID sensors were utilized in the testing to help determine the levels of styrene over various periods of time. Information gathered from this lab scale study test can be directly correlated to safe levels of styrene emission over a set period.
2. **Study 2 – Field Study**
   The field study was conducted to validate the results found from the lab scale study. The same PIDs used for the lab scale study were applied in the field to an installation operation. Here, we could see how the styrene emissions reacted in a real refrigerator transport truck and job site to make a more accurate determination of crew and public safety.

4. METHODOLOGY

The methods used for data acquisition in the lab scale study and the field study are performed in different manners. However, the information gathered from each study can be directly correlated to the other and help improve our knowledge of safe styrene levels.

4.1 Lab Scale Study

The first step taken in completion of the lab scale study is to create a testing chamber. The TTC (Trenchless Technology Center) modified a chest freezer to be the secure temperature-controlled testing chamber. The chamber is fitted with four outlets where the styrene emissions could be recorded. The TTC wet-out all the liners in-house using various material coating liners, resin, rollers,

and vacuum pumps. Both of ends of the liners were closed off using a nylon wrap and duct tape to ensure that there was no styrene escaping from either end. On completion of the wetout process, the resin-impregnated uncured liner is to be placed in the secure chamber. The goal is to compare the baseline VOC taken in the chamber prior to loading and compare it to the buildup of styrene levels over a set period. The actions taken simulate the uncured liners in the refrigerated transport truck prior to opening the doors at a construction site.

4.2 Field Study

To perform the field study Joel Wells and John Kraft visited several liner installations for the purpose of monitoring the uncured liner transport truck. Modifications to the refrigerated truck were made to have PIDs onboard in the cab. The modifications consisted of drilling holes in the refrigerated area and running teflon tubing to the PIDs that were safely secured at the passenger seat. At each installation site, measurements of styrene emission were taken each time the doors opened to install a liner. Data was measured at the back of the truck from the ground and chest height at the middle and front of the chamber. We also took note of each time the door opened to load and unload the trash left over from the installation.

5. EQUIPMENT

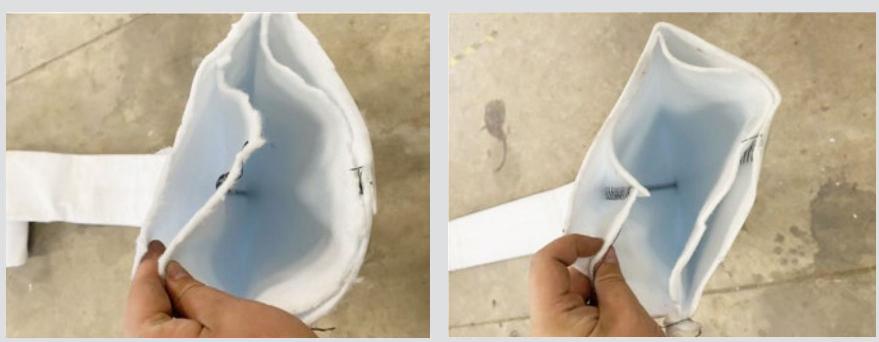
The equipment shown in the images below was vital to the determination of safe styrene levels in both the lab and field studies.

5.1 Lab Scale Study

Secure testing chamber that represents the refrigerated transport truck is shown

Resin Solution

Honeywell MiniRAE PIDs



Two examples of uncured liners are shown

Shown above is the vacuum (left) and the roller (right) used in the wetting out process

5.2 Field Study

***Note: The Honeywell PID sensors depicted in 5.1 (lower left) were also vital to the field data collection.

The "Reefer" or refrigerated truck used for wetted out liner transportation

CIPP shooter (left) and the emission stack (right)

6. RESULTS

The following sections represent the data logged for both the lab and field studies. There are graphical representations available for both methods of study that represent the data collected.

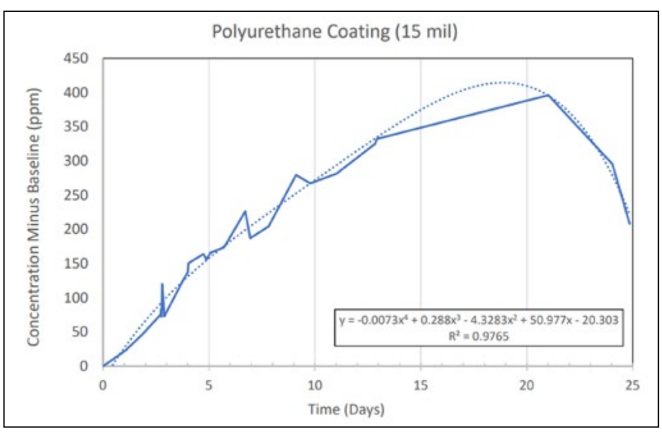


Figure 1. Graphical representation of the 15-mil PU liner

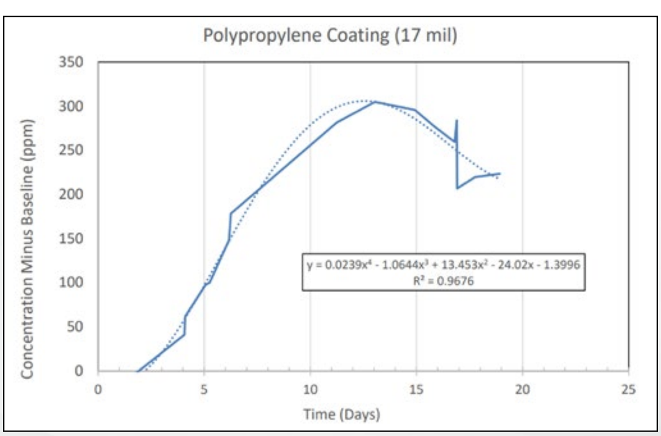


Figure 2. Graphical representation of 17-mil PP

6.1 Lab Scale Study

The results of the lab scale study are illustrated in figures 1-3. The figures show the concentration of the measured styrene levels versus the amount of time. The three liners that has readings taken are as follows: 15-mil thick polyurethane (PU), 17-mil thick polypropylene (PP), and a 24-mil thick polyurethane. Consistent styrene to volume ratios were used for all three tests.

The data plotted above gives a trend as to how the different liner thicknesses effect the breakthrough time. As expected the thinner liners, the 15-mil and 17-mil, allowed for a quicker breakthrough time, both being in the first two days. However, the 24-mil did not see any breakthrough until the sixth day of testing. It should also be noted that the 24-mil liner never saw a decrease in concentration whereas the other liners both saw decreases after a peak was reached. It should be noted that styrene thresholds peaked between 350-400 ppm. This measurement shows that there is an upper limit that can be validated by the field study portion of the testing.

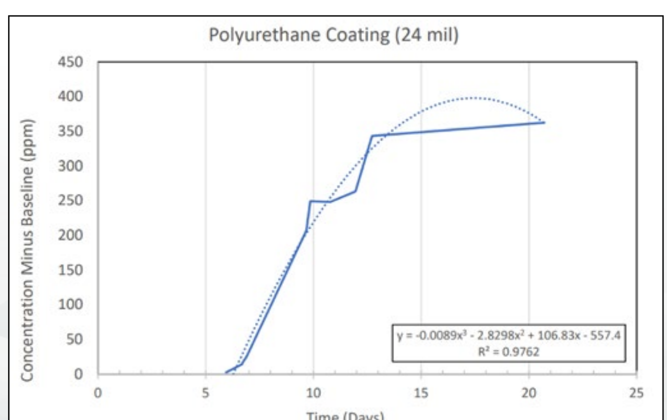


Figure 3. Graphical representation of the 24-mil PU

Coating Material	Breakthrough Point Time	Measured Max Conc. (ppm)	Modeled Max Conc. (ppm)	% Resin by Storage Volume
PU (15 mil)	1 day	396	410	5.6
PP (17 mil)	2 days	305	305	5.6
PU (24 mil)	6 days	362	397	5.6

Table 1. Summarization of maximum styrene concentrations

6.2 FIELD STUDY

The following information represents the data collected from the two installation sites that were visited by the TTC staff. The data shows the tracing of the breakthrough time after liners were loaded onto the reefers at the wet-out facility.

6.2.1 Tampa, Florida Information and Initial Breakthrough

Table 2 logs the liner characteristics for each of the six installations that took place in Tampa. The trucks were loaded on July 15th while installations took place on the 19th, 20th, and the 22nd. The truck that stored the liners measured at 24 x 8 x 8 feet or 1,536 cubic feet.

Installation Number	Coating Material	Coating Thickness (mils)	Liner Thickness (mm)	Liner Diameter (in) / Wet Tube Length (ft)	Estimated Resin Weight (lbs)
1	PP	17	6	7.75 / 353	962
2	PP	17	6	7.75 / 246	671
3	PP	17	6	7.75 / 106	289
4	PP	17	6	10 / 356	1,200
5	PP	17	6	7.75 / 305	831
6	PP	17	6	7.75 / 50	136

Table 2. Summarization of liner characteristics

Figure 4 represents the data logged on July 15th when the truck was loaded. As seen in the graph there is a rapid rise in concentration up to around 250 ppm when liners are loaded with a gradual decrease after six hours to around 150 ppm due to the cooling of the truck.

6.2.1.1 Installation 1

The first installation took place on July 19th, four days after the loading of the truck. Figure 5 illustrates the average emission concentrations versus the time of the installation. Table 3 logs the readings taken when the doors of the truck were open and spot-checking readings that were measured from the tailgate of the truck during the installation.

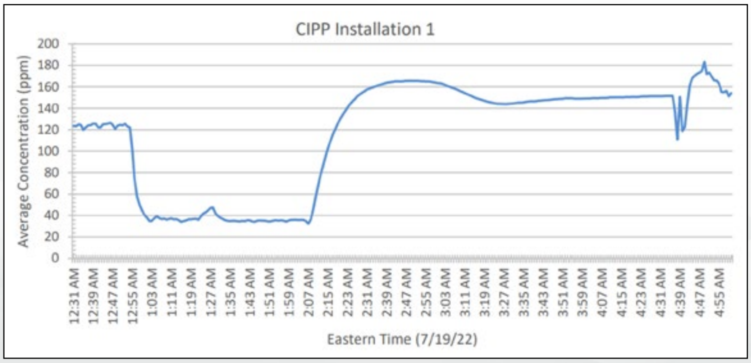


Figure 5. Graphical illustration of the average concentration during installation 1

Date	Time	Action	Spot Check Concentration (ppm)
7/19/22	12:33 AM	Opened door – Spot check reading 1	191
	12:35 AM	Swapped PID #14 for #11	-
	12:36 AM	Spot check reading 2	99 - 143
	12:41 AM	Spot check reading 3	43 - 61
	12:44 AM	Spot check reading 4	60
	12:50 AM	Spot check reading 5	9
	12:54 AM	Spot check reading 6	45
	1:00 AM	Spot check reading 7	43 – 56
	1:01 AM	Spot check reading 8	43
	1:05 AM	Spot check reading 9	65 – 73
	1:10 AM	Spot check reading 10	56
	1:16 AM	Spot check reading 11	47
	1:23 AM	Spot check reading 12	45
	1:33 AM	Spot check reading 13	43
	1:44 AM	Spot check reading 14	28
	1:47 AM	Closed door	-
	4:17 AM	Opened door to store scraps	-
	4:18 AM	Closed Door (<1 minute)	-
	4:19 AM	Opened door for a couple seconds	-

Table 3. Installation 1 details and readings

The data collected shows that there was a decrease in concentration to less than 50 ppm when the doors were open, but an increase in concentration to 170 ppm after 30 minutes of the doors closing. The only other notable decrease was when the doors were opened once more for the loading of trash. The concentration increased as it had before once the doors were closed.

6.2.1.2 Installations 2 and 3

Installations 2 and 3 were performed on July 20th, producing a similar trend to installation 1. Figure 6 illustrates the average concentration during the period in which the two installations took place. Table 4 logs the readings taken when the doors of the truck were open and spotchecking readings that were measured from the tailgate of the truck during the installation.

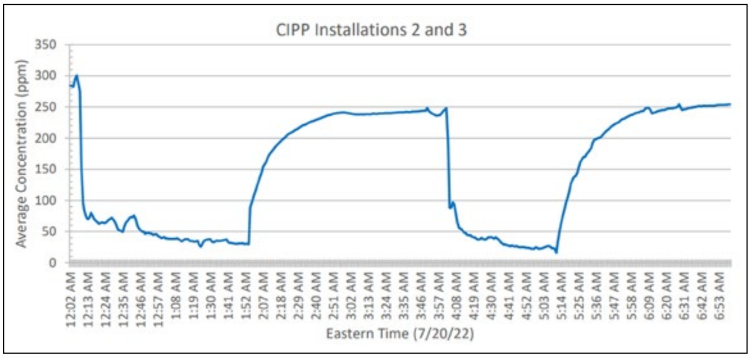


Figure 6. Graphical illustration of the concentration data from installation 2 and 3

Date	Time	Action	Spot Check Concentration 1 (ppm)
7/20/22	12:02 AM	Opened door - Installation 2	-
	12:03 AM	Spot check reading 1	258
	12:05 AM	Spot check reading 2	120
	12:10 AM	Spot check reading 3	50
	12:15 AM	Spot check reading 4	44
	12:21 AM	Spot check reading 5	75
	12:26 AM	Spot check reading 6	56
	12:35 AM	Spot check reading 7	68
	12:45 AM	Spot check reading 8	44
	12:55 AM	Spot check reading 9	35
	1:00 AM	Spot check reading 10	37
	1:22 AM	Spot check reading 11	32
	1:23 AM	Spot check reading 12	26

Table 4 (1). Installation 2 and 3 details and readings

Date	Time	Action	Spot Check Concentration 1 (ppm)
	1:32 AM	Spot check reading 13	23
7/20/22	1:40 AM	Spot check reading 14	32
	1:48 AM	Spot check reading 15	25
	1:49 AM	Closed door	-
	3:56 AM	Opened door - Installation 3	-
	3:59 AM	Spot check reading 1	172
	4:00 AM	Spot check reading 2	129
	4:03 AM	Spot check reading 3	89
	4:08 AM	Spot check reading 4	35
	4:39 AM	Spot check reading 5	13
	5:00 AM	Spot check reading 6	26
	5:03 AM	Spot check reading 7	23
	5:05 AM	Closed door – Spot reading 8	4

Table 4 (2). Installation 2 and 3 details and readings

The data presented in Figure 6 and Table 4 shows that the emission concentration dipped below 40 ppm while the doors were open for the installation. Those values are below the recommended exposure levels from OSHA and NIOSH. Once doors were closed there was an increase in concentration to 250 ppm. The spot check readings for installation 2 matched closely to the readings from inside the truck, while installation 3 spot check readings read a bit lower than the truck values.

6.2.1.3 Installation 4

Installation 4 took place later in the day on July 20th. Figure 7 represents the average concentration for the installation. Table 5 logs the readings taken when the doors of the truck were open and spot-checking readings that were measured from the tailgate of the truck during the installation.

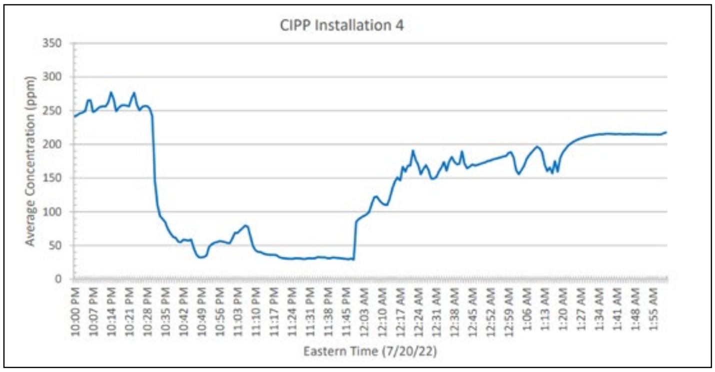


Figure 7. Graphical illustration of average concentrations for installation 4

Date	Time	Action	Spot Check Concentration 1 (ppm)
7/20/22	10:24PM	Opened door - Installation 4, Spot check reading 1	374
	10:26PM	Spot check reading 2	194
	10:28PM	Spot check reading 3	132
	10:30PM	Spot check reading 4	131
	10:36PM	Spot check reading 5	62
	10:42PM	Spot check reading 6	38
	10:52PM	Spot check reading 7	62
	10:58PM	Spot check reading 8	87
	11:03PM	Spot check reading 9	54
	11:12PM	Spot check reading 10	38
	11:18PM	Spot check reading 11	20
	11:29PM	Spot check reading 12	18
	11:32PM	Spot check reading 13	27
	11:38PM	Spot check reading 14	15
	11:45PM	Spot check reading 15	20
	11:48PM	Closed doors – Spot check reading 16	28

Table 5. Installation 4 details and readings

For installation 4, when the doors were opened, the concentration dropped from 250 ppm to below 50 ppm. Once the doors were shut the concentration rose to 215 ppm. The spot-check data from Table 5 are similar to the readings taken inside the truck, however the readings taken at the tailgate at the beginning of the install were higher than readings taken later.

6.2.1.4 Installations 5 and 6

Installations 5 and 6 took place on July 22nd. Figure 8 represents the average concentration for the installation. Table 6 logs the readings taken when the doors of the truck were open and spotchecking readings that were measured from the tailgate of the truck during the installation.

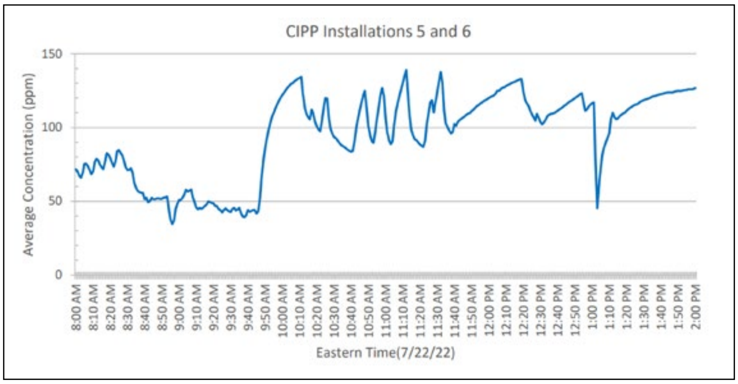


Figure 8. Graphical illustration of average concentrations for installations 5 and 6

Date	Time	Action	Spot Check Concentration 1 (ppm)
7/22/22	8:26 AM	Opened door - Installation 5, Spot check reading 1	292 - 429
	8:28 AM	Spot check reading 2	101
	8:30 AM	Spot check reading 3	68
	8:32 AM	Spot check reading 4	84
	8:41 AM	Spot check reading 5	28
	8:45 AM	Spot check reading 6	64
	8:50 AM	Spot check reading 7	57
	8:55 AM	Spot check reading 8	33
	9:00 AM	Spot check reading 9	59
	9:15 AM	Spot check reading 10	30
	9:20 AM	Spot check reading 11	28
	9:25 AM	Spot check reading 12	33
	9:27 AM	Spot check reading 13	33
	9:30 AM	Spot check reading 14	23
	9:38 AM	Spot check reading 15	18
		Spot check reading 16	31
	9:41 AM	Closed door	-
	12:55 PM	Opened door – Installation 6, Spot check reading 1	246 – 383
	12:56 PM	Spot check reading 2	115 - 194
	12:57 PM	Closed door	-

Table 6. Installation 5 and 6 details and readings

When doors opened the average concentration dropped from 80 ppm to 50 ppm and below. Upon closing the doors concentration rose to approximately 130 ppm. Measurements for installation 6 are very similar with a drop to 50 ppm and a rise of 130 ppm. Some of the spot check readings measured higher than readings taken in the truck. This difference in readings could be due to styrene being heavier than air and settling at the floor of the truck where the readings were being taken.

6.2.2 Milwaukee, Wisconsin Information and Initial Breakthrough

Table 7 logs the relevant coating and liner characteristics all ten of the installations that were performed in the Milwaukee area. The truck was loaded with the liners on August 26th at the wet-out facility. Installation 1 and 2 took place on the 29th, installation 3 on the 30th, installations 4 and 5 on the 31st, installations 6, 7, 8 on September 1st, and installation 9 and 10 on the 2nd. The truck that the liners were stored on measured 26 x 7.75 x 7.5 feet or 1,511 cubic feet.

Installation Number	Coating Material	Coating Thickness (mils)	Liner Thickness (mm)	Liner Diameter (in) / Wet Tube Length (ft)	Estimated Resin Weight (lbs)
1	PU	15mils	4.5	7.8 / 390	826
2	PU	15mils	4.5	7.8 / 240	504
3	PU	15mils	6.0	7.8 / 676	1,811
4	PU	15mils	4.5	7.8 / 378	801
5	PU	15mils	4.5	7.8 / 310	655
6	PU	15mils	4.5	7.8 / 192	401
7	PU	15mils	4.5	7.8 / 218	457
8	PU	15mils	4.5	9.875 / 174	457
9	PU	15mils	4.5	7.8 / 341	721
10	PU	15mils	4.5	7.8 / 199	416

Table 7. Coating and liner characteristics at the Milwaukee area installation

Figure 9 illustrates the initial concentration readings taken when the truck was loaded. Once loaded there is an immediate rise in concentration to approximately 250 ppm.

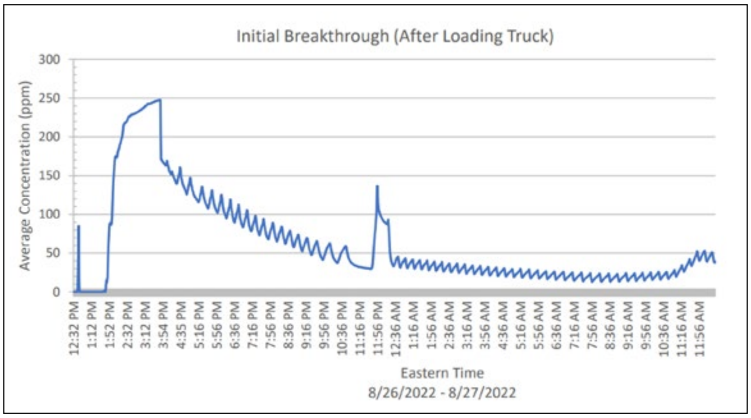


Figure 9. Initial concentration readings taken when truck was loaded

6.2.2.1 Installation 1

The first installation took place three days after the loading of the trucks, on August 29th. Figure 10 represents the average concentration for the installation. Table 8 logs the readings taken when the doors of the truck were open and spot-checking readings that were measured from the tailgate of the truck during the installation.

Differing from the data collected in Tampa, the initial opening of the doors did not show a drop at installation 1. After the doors had been opened for some time, there was a drop to approximately 60 ppm. Once doors were closed, the

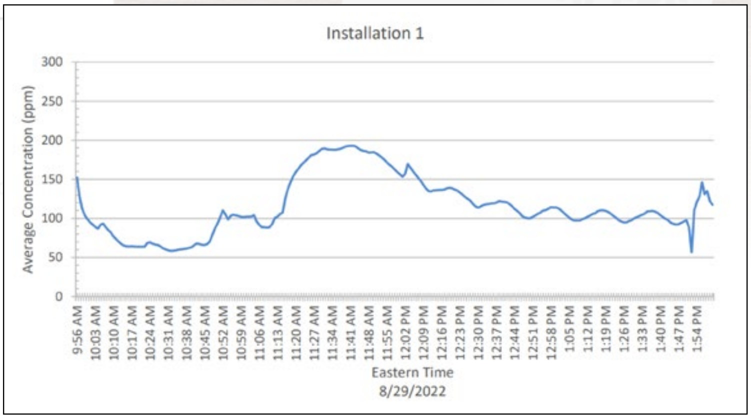


Figure 10. Graphical illustration of average concentration during installation 1

Date	Time (Eastern Time)	Action	Spot Check Concentration (ppm)
8/29/22	10:37AM	Opened door - Installation 1, Spot check 1	637
	10:51AM	Spot check 2	53
	10:57AM	Closed door	95
	1:45PM	Opened door to store scraps, Spot check 3	550
	1:46PM	Closed door	-

Table 8. Installation 1 details and readings

concentration rose to 190 ppm and eventually settled down in the range of 100 ppm mark. Concentration dropped again when the doors opened for trash to be loaded and rose upon the closing of the doors.

6.2.2.2 Installation 2

Installation 2 occurred later in the day of August 29th, producing a similar trend to the previous install. Figure 11 represents the average concentration for the installation. Table 9 logs the readings taken when the doors of the truck were open and spot-checking readings that were measured from the tailgate of the truck during the installation.

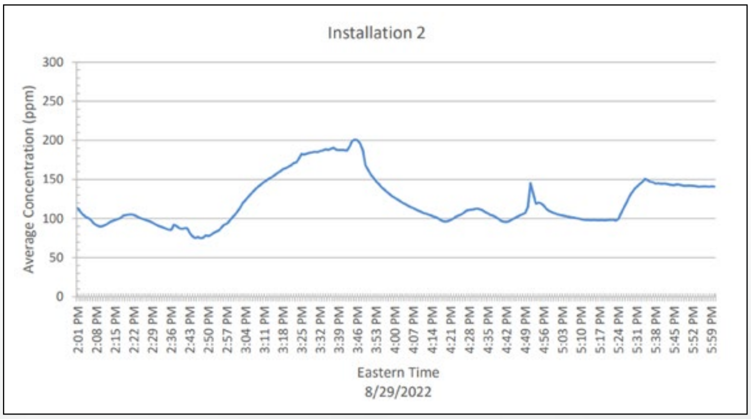


Figure 11. Graphical illustration of average concentration during installation 2

There was only a slight drop in concentration when the doors were opened and an increase to 200 ppm when the doors were shut. There was not a change in concentration detected when

Date	Time (Eastern Time)	Action	Spot Check Concentration (ppm)
8/29/22	2:28PM	Opened door - Installation 2	-
	2:32PM	Spot check 1	42
	2:40PM	Closed door, Spot check 2	120
	4:43PM	Open door to store scraps (30 sec), Spot check 3	323 - 473

Table 9. Installation 2 details and readings

the doors were opened to load the scrap at the end of the installation.

6.2.2.3 Installation 3

Installation 3 took place the following day on August 30th. Figure 12 represents the average concentration for the installation. Table 10 logs the readings taken when the doors of the truck were open and spot-checking readings that were measured from the tailgate of the truck during the installation.

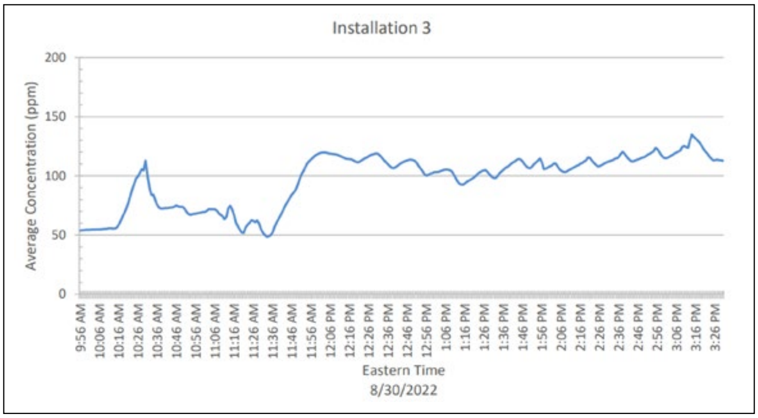


Figure 12. Graphical illustration of average concentration during installation 3

Date	Time (Eastern Time)	Action	Spot Check Concentration 1 (ppm)
8/30/22	10:23AM	Opened door (reason unknown)	
	11:00AM	Opened door - Installation 3, Spot check 1	580
	11:15AM	Spot check 2	71
	11:20AM	Spot check 3	56
	11:21AM	Closed door, Spot check 4	52
	2:01PM	Opened door to store scraps (30 sec), Spot check 5	598
	2:02PM	Spot check 6	458

Table 10. Installation 3 details and readings

For an unknown reason the doors were open at 10:23. They were later opened again 11:00 AM for the installation process. The lowest concentration measured was around 50 ppm while the doors were open and reached a peak of 130 ppm once the doors were closed. Like installation 2 there was no concentration change detected when the doors were opened to load the scrap.

6.2.2.4 Installations 4 and 5

Installations 4 and 5 took place on August 31st. Figure 13 represents the average concentration for the installation. Table 11 logs the readings taken when the doors of the truck were open and spot-checking readings that were measured from the tailgate of the truck during the installation.

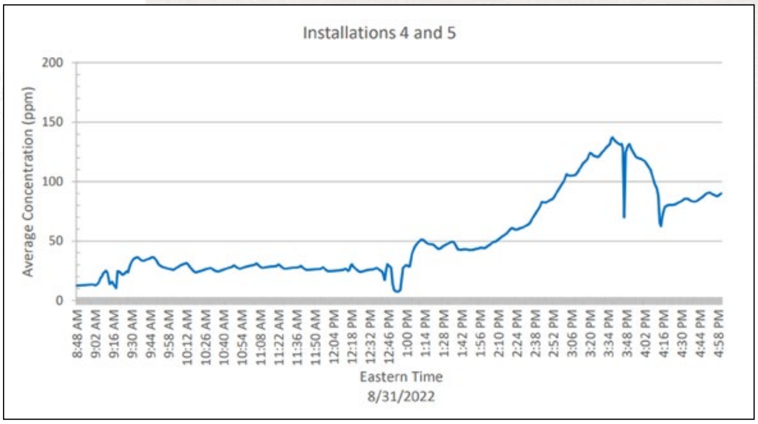


Figure 13. Graphical illustration of average concentration during installations 4 and 5

Date	Time	Action	Spot Check Concentration 1 (ppm)
8/31/22	8:59AM	Opened door - Installation 4, Spot check 1	581
	9:04AM	Spot check 2	138
	9:21AM	Closed Door, Spot check 3	114
	12:10PM	Opened door to store scraps (30sec), Spot check 4	587
	12:11PM	Spot check 5	407
	12:36PM	Opened door - Installation 5, Spot check 1	585
	12:56PM	Closed door, Spot check 2	80
	3:38PM	Opened door to store scraps (30 sec), Spot check 4	589
	3:39PM	Spot check 5	502
	4:05PM	Opened door to dump trash	-
	4:08PM	Closed door	-

Table 11 (2). Installation 4 and 5 details and readings

Before the doors were opened, the readings were comparatively low coming in at around 12 ppm. There was hardly any change in concentration once the doors were opened in installation 4 and a slight increase once they were closed. Going into installation 5 the concentration read around 25 ppm and dropped to 10 ppm while the doors were opened. Upon closing the doors, the concentration met a peak of 140 ppm. There were slight decreases when the door was open to load the trash and when the trash was dumped as the truck made its way back to the warehouse.

6.2.2.5 Installation 6

Installation 6 took place on September 1st. Figure 14 represents the average concentration for the installation. Table 12 logs the readings taken when the doors of the truck were open and spotchecking readings that were measured from the tailgate of the truck during the installation.

6.2.2.6 Installations 7 and 8

Installations 7 and 8 took place later in the day on September 1st. Figure 15 represents the average concentration for the installation.

Table 13 logs the readings taken when the doors of the truck were open and spot-checking readings that were measured from the tailgate of the truck during the installation.

The measurements taken show that there was a decrease in concentration from 65 to 50 ppm while doors were open, and peaked at 120 ppm prior to installation 8. During the second install, the concentration dropped to 50 ppm and then increased to 100 ppm once the doors were shut. There was a slight decrease in the concentration the first time the doors were opened for the storage of the scraps but not change was measured the second time.

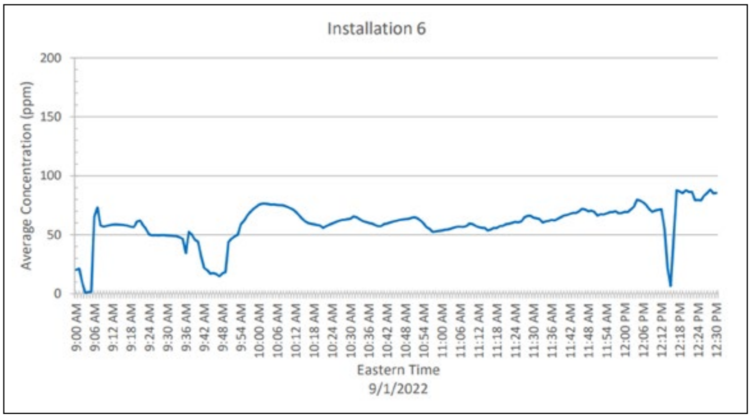


Figure 14. Graphical illustration of average concentration during installation 6

Date	Time (Eastern Time)	Action	Spot Check Concentration 1 (ppm)
9/1/22	9:30AM	Opened door - Installation 6, Spot check 1	617
	9:35AM	Spot check 2	135
	9:45AM	Closed Door, Spot check 3	155
	12:07PM	Opened door to store scraps (30sec), Spot check 4	538
	12:08PM	Spot check 5	473

Table 12. Installation 6 details and readings

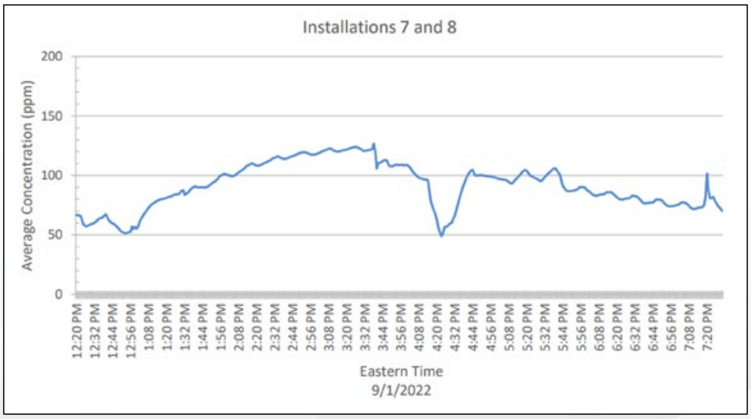


Figure 15. Graphical illustration of average concentration during installation 7 and 8

Date	Time	Action	Spot Check Concentration 1 (ppm)
9/1/22	12:30 PM	Opened door - Installation 7, Spot check 1	481
	12:43 PM	Spot check 2	65
	12:50 PM	Closed Door, Spot check 3	95
	3:30 PM	Opened door to store scraps (30 sec), Spot check 4	421
	3:31 PM	Spot check 5	310
	4:06 PM	Opened door - Installation 8, Spot check 6	383
	4:17 PM	Spot check 7	49
	4:22 PM	Closed Door, Spot check 8	56
	4:40 PM	PID 14 Reconnected*	-
	7:11 PM	Opened door to store scraps (30 sec), Spot check 9	345
	7:12 PM	Spot check 10	134

Table 13. Installation 7 and 8 details and readings

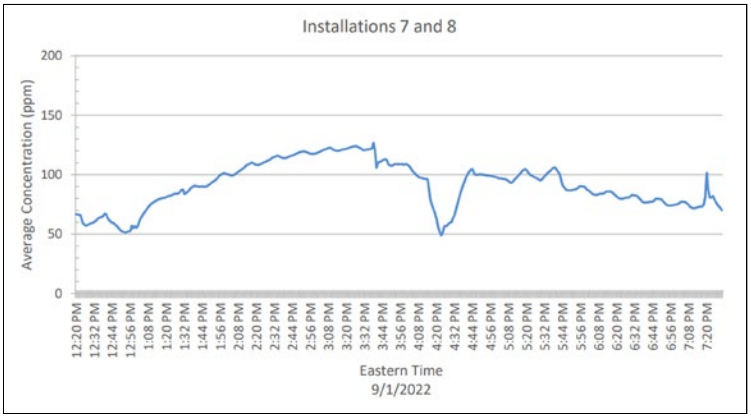


Figure 16. Graphical illustration of average concentration during installation 9 and 10

Date	Time	Action	Spot Check Concentration 1 (ppm)
9/2/22	9:56 AM	Opened door - Installation 9, Spot check 1	419
	10:26 PM	Spot check 2	73
	10:28 AM	Closed door, Spot check 3	125
	1:58 PM	Opened door - Installation 10, Spot check 4	323
	2:10 PM	Spot check 5	32
	2:15 PM	Closed door, Spot check 6	75

Table 14. Installation 9 and 10 details and readings

Installation Number	Date	Min Conc. After Opening (ppm)[1]	Max Conc. After Closing (ppm)[2]	Total # of Resin on Truck[3]	% Resign by Total Volume[4]
Tampa, Florida Sites					
Truck Loaded	7/15/22	-	245	4,089	
1	7/19/22	35	260	4,089	3.3%
2	7/20/22	30	250	3,127	2.5%
3	7/20/22	15	250	2,456	2.0%
4	7/20/22	30	215	2,167	1.8%
5	7/22/22	37	135	967	0.8%
6	7/22/22	45	127	136	0.1%
Milwaukee, Wisconsin Sites					
Truck Loaded	8/26/22	-	247	7,049	
1	8/29/22	60	190	7,049	5.9%
2	8/29/22	75	200	6,223	5.2%
3	8/30/22	50	130	5,719	4.8%
4	8/31/22	10	35	3,908	3.3%
5	8/31/22	10	140	3,107	2.6%
6	9/1/22	15	75	2,452	2.1%
7	9/1/22	50	120	2,051	1.7%
8	9/1/22	50	105	1,594	1.3%
9	9/2/22	40	170	1,137	1.0%
10	9/2/22	50	N/A	416	0.3%

1. Lowest minimum number recorded by PIDs after door opened.
2. Highest maximum number recorded by PIDs after door closed.
3. Total pounds of resin on the truck at beginning of installation.
4. (Volume of Resin / Total Storage Volume) X 100%

Table 15. Summarizations of key measurements from Tampa and Milwaukee

6.2.2.7 Installations 9 and 10

Installations 9 and 10 took place on September 2nd. Figure 16 represents the average concentration for the installation. Table 14 logs the readings taken when the doors of the truck were open and spot-checking readings that were measured from the tailgate of the truck during the installation.

After the doors had been opened for the installation 9, there was a decrease in concentration down to 40 ppm. Once the doors were closed there was an increase and a peak of 170 ppm was reached that would soon level off to 100 ppm. Once the doors were opened for the final installation, the concentration was measured to be 50 ppm.

6.2.3 Discussion of Data from the Two Field Studies

Depicted below in Table 15 is a summarization of the key measurements taken from both Tampa, FL and Milwaukee, WI. The liners installed in Florida were a 17-mil PP coated liner, while the liners that were installed in Wisconsin were a 15-mil PU coated liner.

In the field, with similar coatings and thickness, the breakthrough curve was much steeper than what was found in the lab scale study. Although the maximum concentrations measured in the field were similar or less than what was discovered in the lab, it was not possible to replicate a similar breakthrough curve. Figure 17 below shows the initial breakthrough up to the peak as the truck was loaded in Wisconsin and compares it to the same material in the lab.

As seen in Figure 17, even though the breakthrough is immediate, the rate of increase is much higher in the field versus the lab. This could arise from differing conditions between the field study and the lab study. The chamber in the lab study was never opened

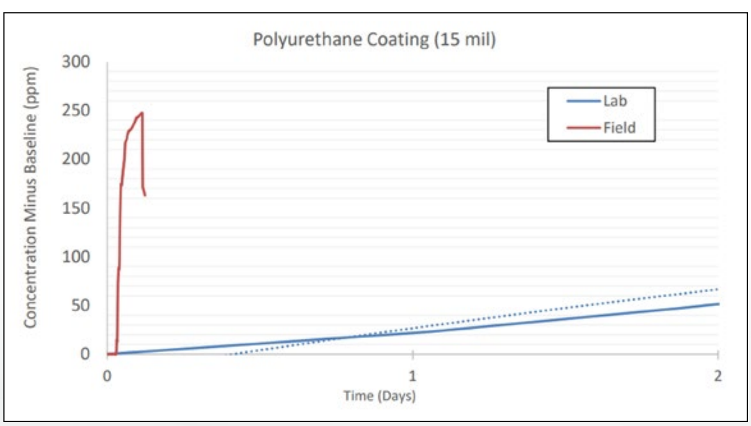


Figure 17. Comparison of initial breakthrough time (Milwaukee vs. Lab)

whereas the reefer was opened multiple times. Another factor is that the ends of liners were sealed in the lab but none of the liners in both field studies were sealed. There is also a difference between the circulation system of the reefer compared to the lab testing chamber.

Both field studies followed the same trend. As the doors were opened to perform the installation, the concentration would decrease. Once the doors were shut, there would be an increase until the concentration reached a peak and would then begin to decrease over time. Upon reviewing the data displayed in Table 15, as each liner was removed from the truck the concentration would decrease and continue to decrease as the week went on.

7. CONCLUSIONS

The time to breakthrough is at least partially based on the materials used and the thickness of those materials. For the same material of different thicknesses (i.e., PU at 15 mils vs 24 mils) the thinner liner allowed breakthrough to happen sooner. Once the door of the cold storage or transport vehicle is open, emissions levels drop very quickly to below OSHA and NIOSH recommended levels. For the two different contractors who were followed, the data showed that over the course of a week of installations the styrene levels slowly reduced each day after liners were removed for installs. Although that may seem intuitive, there is still residual styrene in the storage trucks to be aware of even after all liners have been removed. In the field, for similar coatings and thickness, breakthrough concentrations increased more quickly than what was observed in the freezer test even for similar percent resin to total storage volume values. This could have been due to difference in conditions between the field and lab. Although max concentrations in the field were similar or less than what was observed in the lab, replicating breakthrough curves in the lab that were similar to the field was not achieved. Some spot check readings at both field sites were higher than the concentrations measured inside the truck and those measured in the lab. This was likely due to the fact that styrene is heavier than air and the spot check readings were taken at the floor level of the truck tailgate each time.

8. REFERENCES

Louisiana Tech Trenchless Technology Centers "NASSCO CIPP Emissions Phase 3 Evaluation of Styrene Emissions Associated with Various CIPP Coatings in Refrigerated Storage Final Report" (Matthews, Matthews, Alam, Eklund, Wells, Kraft)

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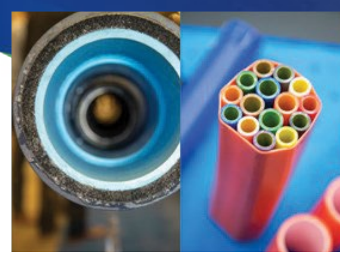

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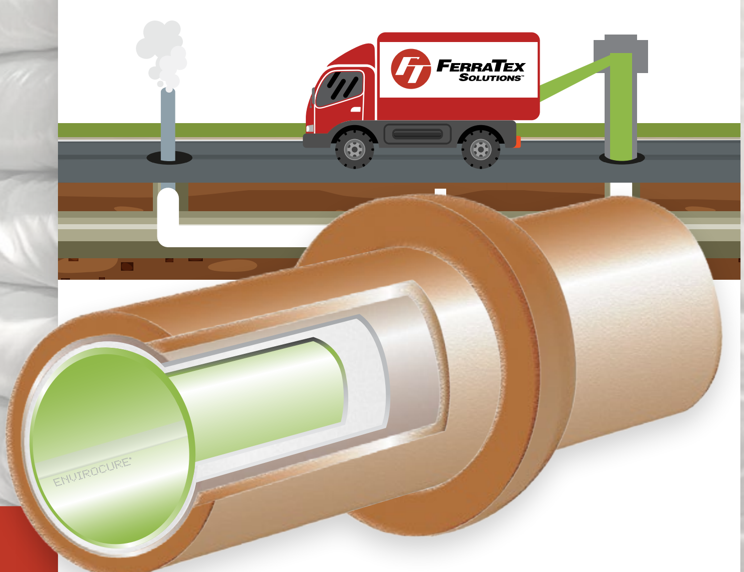

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