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TRENCHLESS NORTH AMERICA

The Official Magazine of the North American Society for Trenchless Technology

No-Dig 2024 Outstanding Paper – New Installations

No-Dig 2024 Outstanding Paper – Rehabilitation

WINTER 2025 TECHNICAL EDITION

NASTT 2025 NO-DIG SHOW TECHNICAL PROGRAM PREVIEW

WINTER 2025
Volume 15 • Issue 1


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The Official Magazine of the North American Society for Trenchless Technology

WINTER 2025 – VOLUME 15, ISSUE No. 1

13 NASTT 2025 NO-DIG SHOW TECHNICAL PROGRAM PREVIEW!

For the first time in 10 years, the NASTT No-Dig Show is returning to Denver, CO. 2025 is anticipated to be the most highly-attended No-Dig Show yet. The "New Heights. Underground." motto reflects the increased growth and importance of trenchless in providing cost-effective environmentally friendly solutions. This issue is a preview of the core Technical Program, now with seven full tracks of informative presentations from industry experts.

MARCH 30-APRIL 3 | DENVER, CO
NASTT NO-DIG SHOW 2025

FEATURES

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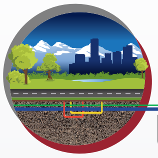

WELCOME TO THE WINTER 2025 EDITION OF NASTT'S TRENCHLESS NORTH AMERICA

Dear NASTT Members and Trenchless Advocates:

As we usher in 2025, NASTT's 35th anniversary, it's a pleasure to welcome you to the Winter Edition of Trenchless North America, our annual technical issue. This edition is packed with valuable insights into the evolving world of trenchless technology, showcasing groundbreaking projects, technical advancements, and the innovators driving our industry forward.

A key highlight of this issue is technical presentations of the No-Dig North 2024 Project of the Year Award winners. These awards celebrate the best of what our industry has to offer, recognizing outstanding Canadian projects that have exemplified excellence in trenchless technology.

In addition to the Project of the Year, this issue features a collection of technical papers that cover a range of topics critical to the advancement of trenchless technology. From new innovations in horizontal directional drilling to advancements in pipeline rehabilitation techniques, these papers offer practical, actionable insights for industry professionals seeking to stay at the forefront of our field. I encourage you to dive into these articles and consider how these technologies can be applied to your own projects.

We also recap the highly successful 2024 No-Dig North, held in Niagara Falls, with a record number of exhibitors and attendees, an exceptional lineup of technical sessions and a highly memorable social evening at the Niagara Falls Power Station. For those who were unable to attend or wish to revisit some of the conference's presentations, the proceedings are now available on the NASTT Knowledge Hub, with free access & download available for Members. This is a great resource for anyone seeking to expand their technical knowledge and stay connected to the latest trends in trenchless technology.

Looking ahead, we have announced the Call for Abstracts for the 2025 No-Dig North & ISTT International No-Dig in Vancouver (see pg 8). This event promises to be a significant milestone in our industry, bringing together leaders, engineers, manufacturers and contractors from around the globe to discuss the future of trenchless technology.

Finally, as we step into the new year, we are gearing up for the NASTT 2025 No-Dig Show in Denver this April. The show will feature hands-on training, cutting-edge exhibits, and unparalleled networking opportunities. If you haven't already, be sure to mark your calendar for this unmissable event!

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

"I encourage you to dive into these articles."

"We are gearing up for the NASTT 2025 No-Dig Show in Denver."

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NEW HEIGHTS. UNDER GROUND.

"Our Society and industry are stronger than ever."

"Together, we are shaping the future of our industry."

KEEP THE MOMENTUM GOING!

Dear NASTT Members and Trenchless Champions!

I am thrilled to be starting my term as the Chair of the NASTT Board of Directors. I'd like to thank my predecessor, Matthew Wallin, for his years of dedication to NASTT and his 9 years of service on the Board of Directors. I hope to keep the momentum going! 2025 marks the 35th anniversary of NASTT and our Society and industry are stronger than ever.

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 winter issue of *Trenchless North America* magazine is our technical edition with a focus on innovative projects and technologies within our industry. We are featuring two full technical papers presented during the 2024 No-Dig Show that were awarded Paper of Year based on attendee feedback and expert committee review, as well as four abstracts from the recent No-Dig North conference held in Niagara Falls. Two of these abstracts reflect projects that received the Canadian Project of the Year awards. You can always access our entire library of technical papers and conference proceedings in the Trenchless Knowledge Hub: **https://knowledgehub.nastt.org/**. In this issue you will also learn more about the organizations and projects in our industry in our Eye on Industry and Q & A columns.

I am looking forward to our upcoming conferences. The NASTT 2025 No-Dig Show will be held in Denver, CO, where we will have the opportunity to delve deeper into the realm of trenchless technology. The conference, scheduled from March 30 to April 3, will feature technical paper presentations from experts and thought leaders, providing a platform to explore the latest research and developments in our field. For further information, look for the Technical Program Preview in this winter issue of *Trenchless North America* magazine (see pgs 10 - 19). There will also be a large exhibition hall with industry players displaying their latest and greatest products and services. And you won't want to miss the many networking events to broaden your contact list. 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 Denver.

Looking a bit further into the year, the annual No-Dig North conference will be held in Vancouver, BC, October 27-29. We are excited to partner with the International Society for Trenchless Technology (ISTT) and combine their International No-Dig conference with No-Dig North 2025. If you would like to participate in Vancouver, we are now accepting abstracts, and you can learn more about that on the following pages.

I encourage each of you to actively participate in the upcoming conferences and engage with the magazine content. Your involvement is vital to the success of our community, and I am confident that these initiatives will further strengthen our collective impact. We are always seeking new volunteers to staff our many committees. If you'd like to learn more or volunteer for a committee, please reach out to **info@nastt.org**.

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.

Greg Tippett

Greg Tippett P. Eng., Board Chair
North American Society for Trenchless Technology (NASTT)

Call for Abstracts

SUBMISSION DEADLINE: MARCH 18

The North American Society for Trenchless Technology (NASTT) is now accepting abstracts for its 2025 No-Dig North conference in Vancouver, BC at the Vancouver Convention Centre, October 27-29, 2025. Prospective authors are invited to submit a 250-word abstract outlining the scope of their paper and the principal points of benefit to the trenchless industry.

The abstracts must be submitted by March 18 online:

nastt.org/no-dig-north

NASTT 35 YEARS

Connecting Trenchless Partners

No-Dig North is owned by the North American Society for Trenchless Technology (NASTT), a not-for-profit educational and technical society established in 1990 to promote trenchless technology for the public benefit. For more information about NASTT, visit our website at nastt.org.

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"A unique opportunity to connect with the Contractors, Manufacturers, Engineers, Educators, and Utility Owners who have helped shape the trenchless industry."

– Chris Knott, BTrenchless, 2025 No-Dig Planning Chair

This edition of Trenchless North America magazine features an overview of the technical schedule taking place at the NASTT 2025 No-Dig Show (pages 14-19). Included in the session schedule are interactive forums where audience participation is encouraged. New this year, be sure to check out the Contractor Forum on Tuesday afternoon, April 1. There are an abundance of opportunities for business development, networking, and renewing friendships with trenchless colleagues while at the conference in Denver.

NASTT NO-DIG SHOW 2025 — MARCH 30-APRIL 3 | DENVER, CO

NEW HEIGHTS. UNDER GROUND.

Here's what the 2025 Planning Chair and NASTT Board of Directors Officer-at-Large, Chris Knott of BTrenchless, has to say:

"For the first time in 10 years, the NASTT No-Dig Show is returning to Denver in 2025! Known for its stunning scenery and central location in the U.S., Denver has become one of the most popular destinations for the NASTT No-Dig Show. We're excited to make the 2025 show our most successful yet, with 7 tracks of technical sessions over the course of three days, highlighting innovative trenchless projects from around the world. Attendees will also have the chance to explore a large exhibit hall dedicated to hands-on education and participate in numerous networking events. It's a unique opportunity to connect with the Contractors, Manufacturers, Engineers, Educators, and Utility Owners who have helped shape the trenchless industry. The NASTT 2025 No-Dig Show's motto, "New Heights, Underground," honors both Denver's "Mile High" status and the continued growth of the underground construction industry."

For more information on attending the NASTT 2025 No-Dig Show, visit: www.nastt.org/no-dig-show
Registration is now open and if you register by March 1, you can save with the Early Registration Discount.

DENVER, CO

THE EVENT SPACE

The Colorado Convention Center is a multi-purpose convention center located in Downtown Denver. With 2,200,000 square feet of event exhibition and conference space.

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North American Society for Trenchless Technology

■ Chair ■ Vice Chair ■ Track Leaders

Monday March 31 - Morning

TRACK ▪ ROOM	TRACK 1 ▪ 103	TRACK 2 ▪ 107	TRACK 3 ▪ 111
TRACK TITLE	Microtunneling	HDD	Trenchless 101
TRACK LEADER	DAVE SACKETT	KIM HANSON	BRIAN DORWART
10:00 - 10:25	■ MM-T1-01 Successful Shallow Microtunneling in Venice, Florida	■ MM-T2-01 Crossing The Coosa – Dismissing Historical Assumptions to Provide a Trenchless Solution	■ MM-T3-01 Trenchless Installation Calculations for High Density Polyethylene
10:30-10:55	■ MM-T1-02 Overcoming Geotechnical and Groundwater Challenges with DSPT in Hot Springs, AR	■ MM-T2-02 Mawan Power Upgrading/Renovation Natural Gas Pipeline Project: Mawan Power Plant to Dachan Island	■ MM-T3-02 Trenchless Manhole Rehabilitation: Success is in the Details - Trenchless 101 Session
11:00-11:25	■ MM-T1-03 Boulder Main Sewer Improvements Phase 2 Sanitary Sewer Project	■ MM-T2-03 A Tale of Two HDDs: Crossing the Harbor Channel and Installing a New Ocean Outfall in Ventura, California	■ MM-T3-03 Visualizing the Fundamentals of Sound HDD Design
11:30-11:55	■ MM-T1-04 Constructing Shafts through 200+ Cobbles and Boulders - Challenges and Successes of the Contract 5B Trenchless Crossing	■ MM-T2-04 If at First You Don't Succeed: A Case History of a Difficult HDD Crossing of the Mighty Fraser River	■ MM-T3-04 HDD Intersect Method – Why and How?

Monday March 31 - Afternoon

TRACK ▪ ROOM	TRACK 1 ▪ 103	TRACK 2 ▪ 107	TRACK 3 ▪ 111
TRACK TITLE	Direct Pipe	HDD	Emerging Technologies
TRACK LEADER	PAUL BEARDON	MARK MILLER	NORMAN CHEN
2:30-2:55	■ MA-T1-01 Direct Pipe – Multi Pass Installations Expand Trenchless Capabilities	■ MA-T2-01 Innovations and Lessons Learned from a World Record Length, Large Diameter Subaqueous HDD Crossing Project in Southeastern Virginia	■ MA-T3-01 The Role of Mechanized Shaft Sinking with VSM in Inner-City Applications
3:00-3:25	■ MA-T1-03 A Case Study in Direct Pipe® Thrust Load Prediction	■ MA-T2-02 Evaluation of Hydraulic Fracture Risk Under Regulated Levees for Updated USACE ER 1110-1-1807	■ MA-T3-02 The Electrifying Labyrinth: Navigating the Complexities of Trenchless Cable Installations
3:30-3:55	■ MA-T1-03 World Record 56" Direct Pipe® Landfall Installation	■ MA-T2-03 Installation of Three Force Mains Crossing Hempstead Bay in Nassau County New York by Horizontal Directional Drilling	■ MA-T3-03 Design of DSPT Method for Offshore Wind Landfall Using Tailored Computer Programs and Parameter Sensitivity Analysis

TRACK 4 ▪ 102	TRACK 5 ▪ 104	TRACK 6 ▪ 108	TRACK 7 ▪ 112
Emerging Technologies	CIPP	Wastewater Pipeline Rehabilitation	Condition Assessment
CORY STREET	KALEEL RAHAIM	JACOB CROWE	JAMES SHELTON
■ MM-T4-01 Close Tolerance Pipe Slurrification (CTPS) for the Replacement of Asbestos Cement Pipe	■ MM-T5-01 Aging Infrastructure, Wildlife, and Wetlands: CIPP Lining of a 72-inch Sewer Interceptor in Palo Alto	■ MM-T6-01 From Innovation to Commercialization: A Look at the Next Generation of Spray-In-Place-Pipe (SIPP) Trenchless Rehabilitation Technologies	■ MM-T7-01 Does AI Make a Difference? Case Studies of AI's Impact on Multi-Year Collection Systems Management
■ MM-T4-02 Big Pipes, Big Data: Advances in Metallic Pipeline Condition Assessment	■ MM-T5-02 CIPP-UV Cure to the Rescue: Stafford County Gains First Hand Experience on UV-Cure of 24-inch Sewer Under I-95	■ MM-T6-02 Richmond Large Diameter Geopolymer Sewer Rehab 2018 to 2024. A Look Back and Current Day.	■ MM-T7-02 Challenges in Planning and Implementing Watermain Non-Destructive Testing
■ MM-T4-03 Unique Products Certification Challenges: Proposing Proactive Testing Strategies for Evaluating Technical Performance of Innovative Trenchless Technologies Within and Beyond Certifications	■ MM-T5-03 Tapered Liner Emergency Trenchless Rehab of an 1800's Egg-Shaped Brick Sewer	■ MM-T6-03 Ultra-Violet Cured-In-Place-Pipe Lining of Deer Creek Trunk, a Large Diameter Sewer with Complex Site Constraints	■ MM-T7-03 Age is Just a Number: Shotcrete and Carbon Fiber Extend the Life of an 1860s Aqueduct in Washington, D.C.
■ MM-T4-04 Optimizing Lift Station Performance using Hybrid Trenchless Pressure Pipelining	■ MM-T5-04 A Unique Strategy to Rehabilitate Multiple Large Diameter Gravity and Pressurized Sewer Pipelines	■ MM-T6-04 Obstructions Facing CFRP Strengthening of the CIP Liner in the West Trunk Sewer Pipe - Mississauga, Ontario	■ MM-T7-04 Sanitary Sewer Force Main Assessment in Phoenix - Different Solutions for Different Locations

TRACK 4 ▪ 102	TRACK 5 ▪ 104	TRACK 6 ▪ 108	TRACK 7 ▪ 112
Pilot Tube	Manhole	Gas	Trenchless Research
JON ROBISON	PAUL PASKO	JOHN ALTINYUREK	ASWATHY SIVARAM
■ MA-T4-01 Lessons Learned: Sanitary Sewer Project Converted to Pilot Tube Method	■ MA-T5-01 Structural vs. Non-Structural Manhole Rehabilitation	■ MA-T6-01 Bears, Bent Frames and No Time. Lessons Learned in Remote Mountain Top Annular Grouting	■ MA-T7-01 Which Method Should We Use for Estimating the Pmax in HDD? Let's Figure This Out Together Once and for All!
■ MA-T4-02 Five Trenchless Methods Under One House – 5600 S Widening at I-15 in Utah	■ MA-T5-02 Inspection of the LOIS Buoyant Interceptor	■ MA-T6-02 Pipe in Place Surveys of Trenchless Installations	■ MA-T7-02 HDD Cost Saving Methods & Techniques for Fusible PVC Conduit Installation - Champlain Hudson Power Express
■ MA-T4-03 Pilot Tube TBD	■ MA-T5-03 A Tale of Two Cities and a Large Diameter Deteriorated Sewer with In-line Geometric Transitions	■ MA-T6-03 Gas TBD	■ MA-T7-03 Improvements in Effective Stress Estimations in Trenchless Excavations in Soil

■ Technical Sessions

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

Tuesday April 1 - Morning

TRACK ▪ ROOM	TRACK 1 ▪ 103	TRACK 2 ▪ 107	TRACK 3 ▪ 111
TRACK TITLE	Microtunneling	HDD	Project Planning & Delivery
TRACK LEADER	ANIL DEAN	KATE WALLIN & MARY NEHER	GUS O'LEARY
8:00-8:25	TM-T1-01 Closing the Gap in the Perris Valley Pipeline Using 120-inch Diameter Microtunneling	TM-T2-01 Record-Length Application of Interlocking Jointed Steel Casing in the East River Crossing HDD for the Champlain Hudson Power Express® Project	TM-T3-01 Is Low Bid the Best Bid? Prequalifying to Ensure Suitable Contractors and Subcontractors
8:30-8:55	TM-T1-02 Deer Creek Intake Project: Microtunneling, Bypass, and Intake Design	TM-T2-02 Compact Pit Launched Directional Provides Answer for 540 Sewer Lateral Installations in Sensitive Native American Settlement Area	TM-T3-02 Optimizing Noise Management in HDD Projects: Accuracy, Feasibility and Cost Efficiency
9:00-9:25	TM-T1-03 Managing Risks for Rock Microtunneling Through the Left Abutment of Deer Creek Reservoir Dam, Utah	TM-T2-03 League City 36-inch Transmission Main HDD- Insights Gained from Three HDD Installations on a 36-inch Transmission Line	TM-T3-03 Collaborative Solutions for the City of Tampa's Harbour Island Force Main Replacement
9:30-9:55	TM-T1-04 Microtunneling Under Historic Infrastructure in New England in Challenging Ground Conditions	TM-T2-04 HDD for Installation of Airfield Lighting Can Extend Pavement Life and Reduce the Danger of Foreign Object Debris for Aircraft	TM-T3-04 Lessons Learned on Alternative Delivery of Trenchless Projects - What Every Owner Should Consider
10:00-10:25	TM-T1-05 Brunette Avenue: Direct Steerable Pipe Thrusting in a Congested Urban Environment for the Trans Mountain Expansion Project	TM-T2-05 Transforming Real-time Drilling Data Using Advanced Software Solutions for Improved Risk Management in HDD	TM-T3-05 Railroad Crossings via Trenchless Methods
10:30-10:55	TM-T1-06 Hitting the Mark: Crossing the Guadalupe River with the Second Vertical-Curved Microtunnel in the United States	TM-T2-06 The Power Beneath: Overcoming Challenges in HVDC Cable Installation for Offshore Renewables	TM-T3-06 Alternatives to Lump Sum in Horizontal Directional Drilling Projects

TRACK 4 ▪ 102	TRACK 5 ▪ 104	TRACK 6 ▪ 108	TRACK 7 ▪ 112
Pipe Bursting	CIPP	Wastewater Pipeline Rehabilitation	Condition Assessment/Inspection
GEORGE MALLAKIS & MIKE WOODCOCK	BILL MOORE & AMBER WAGNER	TIFFANIE MENDEZ	MAUREEN CARLIN & DREW SPARKS
■ TM-T4-01 Pipe Bursting 101	■ TM-T5-01 Emergency CIPP Repair of PCCP Process Piping at Wastewater Treatment Facility	■ TM-T6-01 Don't Drain the Pond; Rehabilitating the City of New Bedford's Grape Street Collector Sewer	■ TM-T7-01 "The Data All Lives in a Yellow Submerged Thing" Corpus Christi Water Inspects 101-mile Mary Rhodes Pipeline in Single Run
■ TM-T4-02 Omaha Metropolitan Utility District Performs In-House Pipe Bursting Project for Major Potable Water Flow Improvements	■ TM-T5-02 Moonlight State Beach Triple 72" Culvert Rehabilitation with UV CIPP	■ TM-T6-02 Challenging Rehabilitation of a Trunk Sewer Using Sprayed Geopolymer Lining in Ontario, Phase II	■ TM-T7-02 I/I Reduction Success – How Lateral Lining Achieved 80% Reduction in I/I
■ TM-T4-03 The Future of the National Electric Grid: Trenchless Technology's Role	■ TM-T5-03 The Effect of Porosity in Needled Felt CIPP on Short-Term and Long-Term Flexural Properties	■ TM-T6-03 Technical Nuances to Applying Spiral Wound Lining to Sewers with Complex Diversions	■ TM-T7-03 Design and Repair of the Kingsbury Run Branch A Culvert Failure with a Permanent Shotcrete Lining
■ TM-T4-04 Pipe Bursting Proof of Use for Water Main Replacement: Insights from WSSC Water Pilot Project	■ TM-T5-04 Styrene Emission During Cured-in-Place Pipe Installation: A Comparative Analysis of Polyester and Epoxy Resin Liners	■ TM-T6-04 Safety Culture and High-Performance Products Key Elements to Knoxville Live Sewer Pipeline Rehabilitation Project	■ TM-T7-04 Designing Spray Applied Cementitious Liners for Buried Pipe Structures Using an Engineering Solution That Recognizes the True Soil-Structure Interaction Response
■ TM-T4-05 Oro Loma Sanitary District Sewer Replacement Program Using Pipe Bursting	■ TM-T5-05 Preserving Casper's Infrastructure: A Large-Diameter Pipeline Trenchless Rehabilitation Project	■ TM-T6-05 Spiral Wound Rehabilitation in New York City	■ TM-T7-05 Structural Rehabilitation of a Critical 54-inch Sanitary Force Main in Downtown Tampa
■ TM-T4-06 Pipe Bursting Provides Solution for Difficult Ductile Iron Force Sewer Main Replacement in Minnesota	■ TM-T5-06 South Englewood, Colorado 92" Stormwater Pipeline CIPP Rehabilitation, Innovation and Advancements to Overcome Multiple Construction Challenges	■ TM-T6-06 Rehabilitation of Lake Hills Interceptor Sewer in King County, Washington with PVC Spiral Wound Liners	■ TM-T7-06 Critical Design Consideration for a River Crossing Trunk Sewer Rehabilitation - Erin Mills Sanitary Trunk Sewer, Region of Peel, Ontario

■ Technical Sessions

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

Tuesday April 1 - Afternoon

TRACK ▪ ROOM	TRACK 1 ▪ 103	TRACK 2 ▪ 107	TRACK 3 ▪ 111
TRACK TITLE	Large Diameter Tunneling	HDD	Project Planning & Delivery
TRACK LEADER	KYLE WILLIAMS	CORY BAKER	BRENDAN O'SULLIVAN
1:00-1:25	■ TA-T1-01 Denver International Airport Runway and Taxiway Instrumentation and Monitoring	■ TA-T2-01 Large Diameter HDD Steel Pipe Design and Installation Challenges in Hillsborough County, Florida	■ TA-T3-01 Trenchless 101 - Planning for Not-So-Trenchless Large Diameter Trenchless Rehab: Lessons Learned & Case Studies
1:30-1:55	■ TA-T1-02 1 Tunnel, 2 Pipes, 3 Shafts: Water Main Installation Below the Occoquan River	■ TA-T2-02 Introduction of Horizontal Investigation as an Alternative Ground Investigation Method	■ TA-T3-02 Optimization of Mechanical Properties of High Strength Reinforced Cured-in-Place Pipe (CIPP) Liner Composites for Urban Water Infrastructure Rehabilitation
2:00-2:25	■ TA-T1-03 West Gates Dirty Industrial Water Pond Expansion Project: Tunnel Design Challenges at Denver International Airport	■ TA-T2-03 Second Time's the Charm - Challenges Encountered During the Stoney Brook River Crossing	■ TA-T3-03 HDD Design with Construction in Mind
2:30-2:55	■ TA-T1-04 Overcoming Challenges While Tunneling at the Jersey Shore	■ TA-T2-04 PacWave South Trenchless Construction – Geotechnical Considerations	■ TA-T3-04 Multiple Trenchless Crossings of US 98 at Tyndall AFB - Navigating FDOT Rules, Site Constraints, and Installer Capabilities

Wednesday April 2 - Morning

TRACK ▪ ROOM	TRACK 1 ▪ 103	TRACK 2 ▪ 107	TRACK 3 ▪ 111
TRACK TITLE	Auger Boring	HDD	Construction Project Management
TRACK LEADER	SAM BRANCHEAU	MARK MILLER	STEPHANIE NIX-THOMAS
8:00-8:25	■ WM-T1-01 Challenges Faced in Horizontal Auger Boring Within High Strength Basalt Under Two High-Pressure Gas Pipelines	■ WM-T2-01 Challenging HDD Crossing in Northern Alberta: NPS 48 Product Pipe Installation with Over 70m (230 ft) in Elevation Change	■ WM-T3-01 Failing Our Way to Success
8:30-8:55	■ WM-T1-02 You Can Bet on Trenchless: Waterline Replacement on the Las Vegas Strip	■ WM-T2-02 "Trenchless Restoration of Recycled Water Delivery Under the Napa River in Northern California Wine Country"	■ WM-T3-02 Communication is Key: Lessons Learned in Coordinating a Horizontal Directional Drilling Megaproject Across New York State
9:00-9:25	■ WM-T1-03 Beneath the Frost: Trenchless Technology for Winter Resilience	■ WM-T2-03 Application of the Concept of Probabilistic Risk Assessment for the Borehole Stability Evaluation in Horizontal Directional Drilling	■ WM-T3-03 Pipe Ramming for the Frogs
9:30-9:55	■ WM-T1-04 Design Considerations for Thrust Blocks	■ WM-T2-04 Horizontal Directional Drilling (HDD) Alignment and Tensile Force Optimization Using Metaheuristic Algorithms	■ WM-T3-04 Taking a Shot… at the Rehabilitation of a 114" Brick Sewer Down Stream of a Distillery in Louisville, Kentucky, USA

Technical Sessions

TRACK 4 ▪ 102	TRACK 5 ▪ 104	TRACK 6 ▪ 108	TRACK 7 ▪ 112
Grouting	Pipe Ramming	Sliplining	Annual Contractor Forum/ TT Project of the Year
FIRAT SEVER	BRENT JOHNSON	CHAD ANDREWS	ANDREW SPARKS
TA-T4-01 A Track Record of Pipeline Assessment and Rehabilitation: A 10-Year History of Sewer Collection System Improvements in Plymouth, MA	TA-T5-01 Pipe Ramming, Splitting, and Blasting Through Railroad Ballast Obstructions to Install 72-inch Culvert	TA-T6-01 Stormwater Box Culvert Gravity Sewer Slipline	TA-T7-01 Annual Contractor Forum
TA-T4-02 Emergency Investigation and Trenchless Repair of a 48-inch Diameter Sanitary Sewer Interceptor Crossing at Interstate I-49	TA-T5-02 Rehabilitate or Replace Weber Basin's North Salt Lake Pipelines?	TA-T6-02 Rehabilitating a Nearly Century-Old Non-Circular Tile Lined Outfall Sewer Near Active Railroads in the Heart of Los Angeles	
TA-T4-03 Reducing Trenchless Tunneling Risks: The Role of Permeation Grouting	TA-T5-03 Life's Certainties: Death, Taxes, and *hit Flows Downhill…	TA-T6-03 Rehabilitating Los Angeles County Sanitation Districts' Largest Diameter Trunk Sewer - Joint Outfall B Unit 1A – The Saga Continues	TA-T7-03 Trenchless Technology Magazine Projects of the Year Forum
TA-T4-04 Case Studies in Emergency Water Control	TA-T5-04 Navajo Nation Municipal Pipeline HDD Installation	TA-T6-04 Rehabilitating a 100 Year-Old Lock Bar Water Transmission Main – Completing the Job	

TRACK 4 ▪ 102	TRACK 5 ▪ 104	TRACK 6 ▪ 108	TRACK 7 ▪ 112
Pipe Bursting/Pipe Pulling/Pushing	Emerging Technologies	Water Main Rehabilitation	Wastewater
MICHAEL JAEGER	INSHIK PARK	BRENT LINDELOF	DAVID HAUG
WM-T4-01 Trenchless Replacement of Distribution Watermain in North Branch, Minnesota	WM-T5-01 Comparison of AI vs Human Condition Assessment of Sanitary Sewers in Boston, MA	WM-T6-01 Municipal Pipe Bursting Program: Looking Back at More Than a Decade of Successful Water Main Pipe Bursting Replacement at Consolidated	WM-T7-01 City and County of Denver - Jackson Street Storm Drain Improvements
WM-T4-02 Raleigh Water, North Carolina, Upsizes 8-inch Gravity Sewer to 12-inch Via Pipe Bursting in a Major Throughfare	WM-T5-02 HDPE Pipe Wall Thickness for Earthquakes	WM-T6-02 Evaluating the Buckling Effects of Groundwater Hydrostatic Pressure on Polymeric Spray Applied Pipe Liners	WM-T7-02 Tunnel Construction Considerations - A Primer for Beginners
WM-T4-03 Applying Compression Capabilities of Fusible PVC to Trenchless Installation Methods	WM-T5-03 Mechanical Response of Legacy Pipelines Rehabilitated with Trenchless Technologies: Comparison of Tensile Coupon and Full-Scale Test Results	WM-T6-03 Kansas River Bridge Water Main Transmission Crossing Rehabilitation with FFRP	WM-T7-03 Trenchless Winches Key to Massive Sliplining Project for NYC Sewage Regulator Chamber
WM-T4-04 Experimental Assessment of Pipeline Systems Under Biaxial Loading for Trenchless Applications	WM-T5-04 Ice Pigging - Advanced Technology That Reduces the Need for Excavation Prior to a Pipe-Cleaning Project	WM-T6-04 Performance Assessment of Manufactured in-Place Composite Pipe Through Full-Scale Sustained Pressure Testing: A Case Study in Collaboration	WM-T7-04 More Than a Decade of Large Diameter Pipe Rehabilitation Using Geopolymer From One Contractors Perspective

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

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NASTT 2025 No-Dig Show Scholarships Provided to Municipal & Public Utilities

MARCH 30-APRIL 3 | DENVER, CO
NO-DIG SHOW 2025

Municipal and public utility scholarships cover registration and accommodations costs for over 150 delegates attending the 2025 No-Dig Show, March 30 - April 3 in Denver, Colorado!

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 2025?

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 Colorado Convention Center, March 30 - April 3, 2025. 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

New this year! Add a ticket to the Mile High Mixer to your No-Dig registration. Held Sunday evening at the Colorado Convention Center, you'll be able to meet the 2025 Municipal Scholarship recipients and network with other attendees

NASTT 2025 NO-DIG SHOW MUNICIPAL & PUBLIC UTILITY SPONSORSHIPS

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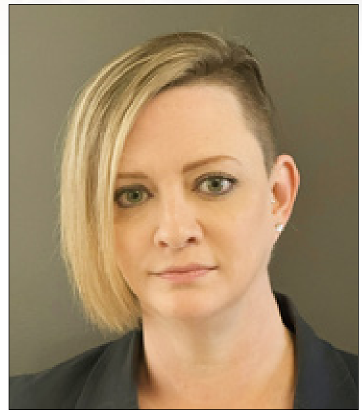
Q&A with Ashley Rammeloo

Ashley's first encounter with NASTT was the 2009 International No-Dig Show in Toronto, which opened up a world of opportunity for learning about the benefits of utilizing trenchless technologies for managing underground infrastructure assets. Currently Director of Water, Wastewater, and Stormwater at the City of London, Ontario she possesses a robust skill set encompassing Project Management, Site Plans, Trenchless Rehabilitation, Spill Response and Employee Training. Recipient of the NASTT Trent Ralston Award for Young Trenchless Achievement in 2013 Ashley is an active volunteer with NASTT and was Program Chair for No-Dig North 2024 in Niagara Falls, October 28 – 30. She shares her ideas on the current and future state of the trenchless technology industry.



London
CANADA

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

My interest in engineering and construction was piqued pretty early in life, towards the end of grade school. An offhand comment made by a teacher sent me off looking into what engineers do. It didn't take long to decide I wanted to go into civil engineering and I focused my high school classes around that path. With a degree in structural engineering, I thought I'd be going into the private sector, designing buildings or bridges. However, after an internship at a small engineering firm, and a presentation by our local City Engineer, I decided to pursue a career in public service after graduation and started with the City of London as an Engineer-in-Training (EIT). I still hadn't given much thought to underground infrastructure though! I was part of the program that rotates the EITs into different service areas and was asked to work in Wastewater & Drainage Engineering. Although I had done a municipal design course as part of my engineering degree, this was my first real exposure to the construction aspect of underground services. It wasn't what I had envisioned doing with my career, but I liked it right away! It has been an unexpected but very rewarding career path. I've had the privilege of spending the last twenty years in the design, construction, management, and operation of my city's critical infrastructure in progressively responsible roles, and now have an expansive view of our work as the Director of Water, Wastewater, and Stormwater.

Outline your experience of first being introduced to trenchless technology methods and applications.

One of my first assignments was to manage the trunk sewer inspection program. It was relatively new and we were using combined sonar and CCTV to assess a part of the system that hadn't been paid much attention to before that. The inspection program then led to the City's first trunk sewer lining project, which I also got to manage. It would be the first of many times I sat in the back of a camera truck in the middle of the night to watch the post-lining inspection. The success of that project led to more trunk lining projects and pilot projects for testing various methods for the inspection and rehabilitation of our wastewater collection system.

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

My first experience with NASTT was the 2009 International No-Dig Show in Toronto. It was a great show and I met a number of people who were quite involved with NASTT and the No-Dig Show. That led to being on the program committee, moderating, and presenting, as well as volunteering for my local chapter (GLSLA). This opened up opportunities for me to absorb a ton of information about trenchless technologies and the possibilities for managing our system. I would like to see an increased presence by NASTT and the local chapters at other industry events. When I attend other water and wastewater conferences, you don't always see a lot about trenchless technology. Having a higher profile at these conferences and encouraging our members to submit papers to those conferences to highlight trenchless projects will go a long way in educating the broader industry on the capabilities of trenchless.

"An unexpected but very rewarding career path!"

"We have no shortage of infrastructure work that needs to be done."

What are your thoughts on the current state of the trenchless industry? What areas do you see evolving in STEM education and post-secondary academics?

One of the most interesting aspects of the industry to me right now is how is Artificial Intelligence going to alter our work processes. The first way that usually comes to peoples' minds is data processing from condition assessments. AI can assist with the gathering, processing, and collating of the data so that our people can make more efficient, informed decisions. I'm interested to see how it is ultimately incorporated into new installation and rehab methods as well. Although its already use in control systems, the potential for its expanded use in monitoring and interpreting data during an installation could mean greater accuracy and lower risk. I think we can all agree that a more efficient and safer work site is ideal! I know some folks view AI as a job killer. I don't see it that way at all. We have no shortage of infrastructure work that needs to be done, and its cyclical, so the industry is not going to disappear. AI lets our people focus on other aspects of the work and can create efficiencies that will reduce individual project costs so that we can do more with our budgets. The jobs and people aren't going anywhere, they'll just shift with technology, just as they have through previous advancements.

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?

I think this is a challenge for every industry! I do think NASTT is an incredibly welcoming and encouraging organization for young professionals, based on my own experience entering this industry very early in my career. The industry is eager to share knowledge and promote the available technologies. I love that NASTT also celebrates young professionals with the

Trent Ralston Young Trenchless Achievement Award, and not just because I'm a past recipient! It's encouraging to know that your work is seen and appreciated by peers and mentors. The student chapters of NASTT are invaluable, as is the work that local chapters do to engage with them. I would like to see this expand even more. And of course, attracting more young professionals to the industry will happen organically as more consultants and municipalities use trenchless technologies, so we need to be engaging all levels so that it trickles down to younger staff as well.

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

I think the industry will face pressure to continuously enhance the capabilities of existing technologies – make it bigger, faster, more adaptable. Conversely, how do we also make trenchless technologies cost efficient for smaller scale jobs? Acceptance and understanding of trenchless technology continues to grow, which increases demand but also changes the demands themselves. I've noticed increased expectations from residents to complete projects trenchlessly over the past few years. They've heard it exists, and they want the lessened disruption on their street and they want their street trees saved during construction. This often highlights other constraints – the size of sending and receiving pits may not fit within the neighbourhood, or there may be a significant cost differential because of the project particulars. We may have a lot of services to reinstate, and those smaller excavations may end up in tree removals as well, meaning you've lost a big benefit of doing it trenchlessly. So as acceptance and understanding improves, the demands on the technologies increase. I look forward to seeing how industry meets them.

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

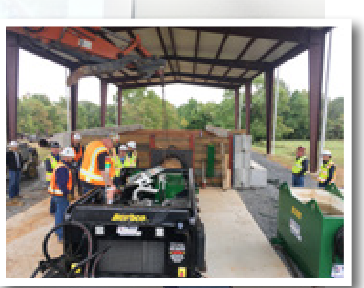
For me it's been that it encourages outside of the box thinking. As someone who is very end-goal driven, I'm always looking for ways to attain our desired outcomes while working around the constraints. Trenchless construction has often provided those ways, or we've found ways to adapt it to meet our needs. I love working with the consultants and contractors to find ways to stretch the capabilities of the technologies and problem solve. We've accomplished a lot of things that we initially thought couldn't be done!

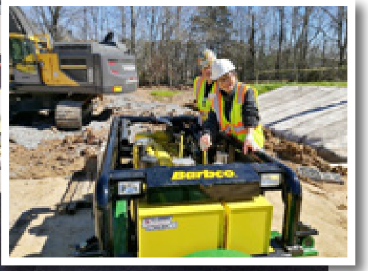
Trenchless Technology Center Hosts 7th Annual Auger Boring School

By: John Kraft, PhD, Trenchless Technology Center

The TTC and its partners are teaming up to offer the latest 3-day Auger Boring School (ABS) from February 25-27, 2025 in Ruston, LA. The field portion of the school will again be held at the Barbera Education and Research Training (BERT) facility and will include direct hands-on instruction. ABS is designed to meet the highly demanding industry of today. Training topics will include auger boring design, application, installation, and rock boring training. The school will include classroom lectures and practical sessions. It will be instructed by the foremost auger boring experts in the country and will be sponsored by Barbco, Trenchless Rental Solutions (TRS), Tri-Loc Trinity Products, U.S. Shoring & Equipment Co., Midwest Mole, Kilduff Underground Engineering, Louisiana 811, Olson Construction Law. The course will cover all aspects of auger boring projects from design to construction, with a special focus on safety. TTC Director of Special Schools Dr. John Kraft, will serve as one of the Course Directors, along with TTC Director, Dr. John Matthews. For more information about the course please contact Dr. John Kraft at jkraft@latech.edu.

This 3-day school has been developed to provide its students with the knowledge needed to understand the important components of Auger Boring & Pilot Tube operations to produce successful projects. In addition to the classroom lectures, hands-on practical scenarios will be held with the actual equipment in a field setting. The course takes place at the LA Tech campus with classroom sessions in the university's Integrated Engineering and Science Education Building and hands-on sessions at the TTC's Barbera Education, Research & Training (BERT) facility, specifically designed and constructed for trenchless technologies. At the end of the Auger Boring School, each attendee will receive 2.4 CEUs – 24 PDHs and a Certificate of Completion.





In addition to classroom sessions, the Auger Boring School features hands-on practical demonstrations

Sessions are instructed by industry professionals featuring cutting-edge technologies

This 3 Day Course is for:

- Contractors
- Engineers
- Project Superintendents
- Foreman/Crew Members
- Estimators
- Public Officials
- Educators
- State Highway Department Reps.
- Regulatory Agency Reps.

The TTC at Louisiana Tech University is a cooperative research center for academia, government, and industry. The Center's mission is to advance trenchless technology by serving as an independent source of knowledge, research, and education in the field. The TTC utilizes a three-pronged approach to accomplish its mission: research & development, education, and technology transfer.

In addition to its research activities, a strong effort has been focused towards the education of engineers, contractors, government agencies and others about the availability and capability of trenchless methods for the solution of difficult underground infrastructure problems. The TTC has worked with various organizations in evaluating and developing new technology for the industry. Industry members contribute financial support, expertise and guidance – principally through the Industry Advisory Board (IAB). Organizations like the Louisiana Contractors' Educational Trust Fund play an important role in supporting the TTC.

John Kraft, Ph.D., *is the Director of the Auger Boring School and Research Associate, Trenchless Technology Center and Adjunct Professor, CE & CET, Louisiana Tech University. He currently serves as a member of the NASTT Board of Directors.*

John Matthews, Ph.D., *is the Director of the Trenchless Technology (TTC) and Eminent Scholar Chair in Construction at Louisiana Tech, with over 20 years of experience in the installation, rehabilitation, and inspection of infrastructure systems. He is Past Chair of the SESTT Chapter Board, and a former member of the NASTT Board of Directors.*

7th Annual Trenchless Technology Auger Boring School

Date: February 25th-27th, 2025
Time: 8:ooAM - 5:00PM daily
Location: Barbera Education, Research & Training (BERT) Facility, Louisiana Tech University TTC

Course Objective:

The Trenchless Technology Center (TTC) at Louisiana Tech University is holding the 7th TTC Auger Boring School (ABS) in 2025. This 3-day school has been developed to provide its students with the knowledge needed to understand the important components of Auger Boring & Rock Boring operations to produce successful projects. In addition to classroom lectures, hands-on practical scenarios will be held with industry equipment. The school will be instructed by industry professionals and will cover all aspects of a project from design to construction.

This 3 Day Course is for:

- Contractors
- Engineers
- Project Superintendents
- Foreman/ Crew Members
- Estimators
- Public Officials
- Educators
- State Highway Dept. Reps.
- Regulatory Agency Reps.

Price Categories

Full Price
$1,795.00

Group (3 or more)
$1,550.00

Early Bird (before New Years '25)
$1,500.00

Early Bird Group
$1,400.00

Course Director

John Kraft, Ph.D.
Director of Special Schools,
Lecturer of Civil Engineering &
Construction Engineering Technology

For more Information Contact:

- **Dr. John Kraft**
  - jkraft@latech.edu
- **Ms. Fredda Wagner**
  - fredda@latech.edu

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AT the end of this course, students will receive 2.4 CEUs – 24 PDH's & a Certification of Completion

NASTT Congratulates its 2024 Trenchless Rising Stars

Trenchless Rising Stars Represent the Future of the Profession

By: Carolyn Hook, NASTT Membership Outreach & Database Manager

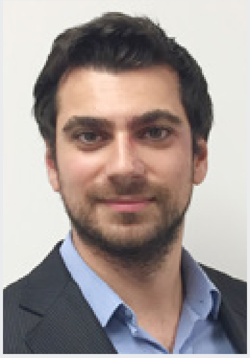
The North American Society for Trenchless Technology is looking to discover early career professionals who are already making impressive strides in the trenchless industry and have great potential to impact the future of the profession. NASTT sees these young professionals as Trenchless Rising Stars.

Trenchless Rising Stars are young professionals whose record reflects ongoing and exceptional growth in their contributions to the profession and increasing levels of leadership, responsibility and sphere of impact. These early career professionals have a track record that reflects a strong career trajectory and the potential to reach the highest levels of achievement in the profession.

David Agan
Bureau of Reclamation

How did you get started in the trenchless industry? *By happenstance I got my start when moving from the East coast to Denver to work for Kilduff Underground Engineering. Todd Kilduff is a great mentor and proponent for the trenchless industry! During my initial interview, I had the opportunity to tour several trenchless projects, and it reinforced my desire to be involved in this field. Trenchless (new installations) projects involve all the cool and exciting aspects of geotechnical design – like ground behavior and classification, dewatering, support of excavation, ground treatment, risk evaluation, and horizontal excavation – often all in one project! By its nature trenchless is very interdisciplinary and getting to work with people in different areas of expertise really expands your knowledge base.*

What career advice would you give to a young person? *Don't be afraid to ask questions. Questions have potential to present different perspectives, open dialogue, show you're engaged and interested and most importantly allow for the continuation of learning.*

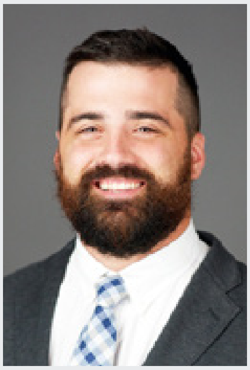


John Altinyurek
Kilduff Underground Engineering

How did you get started in the trenchless industry? *My first introduction to trenchless technologies was thanks to my former manager at WSP, David I. Smith. He had asked me work on a project at DC, and the uniqueness of the concept immediately grabbed my attention. Later I had a chance to get involved heavily with microtunnels on the Bay Park project and realized that trenchless is the future of the underground construction industry.*

How do you explain what you do to someone who has no idea what trenchless technology is? *I usually ask them: "Have you ever had to change your way because the road was closed due to the road being half open? Trenchless avoids doing that."*

Who inspires you and why? *My wife. She is always there when I need her. Unbelievable.*



Bryce Carson
Bond Civil & Utility Construction, Inc.

How did you get started in the trenchless industry? *I grew up in this industry. I started working on my first drill crew while still in school and I have been hooked ever since.*

How do you explain what you do to someone who has no idea what trenchless technology is? *We install pipes for underground utilities anywhere that it is not possible to simply dig a trench from the surface, typically under obstacles such as rivers, railroads or highways.*

What career advice would you give to a young person? *To know what you know and what you do not know – that is true knowledge.*

Share a challenge you overcame and what motivated you to push through? *July of 2023, I joined a new company, Bond Civil & Utility, in order to start up a new Trenchless Division. Every day since has been full of challenges, but having the opportunity to directly shape the business is extremely motivating.*

Daniel McManus
Stantec

How did you get started in the trenchless industry? *I was working with Stantec as an intern in Walnut Creek, CA where I began to learn about trenchless methods and geotechnical investigations. During this time, I was able to work with and by mentored by an excellent group of engineers who I truly credit everything I know now to.*

The best workday I ever had was… *finding out that we were working on a project to improve the water supply in my hometown. It was a very wholesome experience to explain to my friends and family what I do and how the project we are working on will help secure the water supply in our town. Short deadlines can make it easy to have tunnel vision and only focus on the tasks you are assigned for a project. Hearing about this project taking place where I grew up is a constant reminder to me to put myself in the shoes of someone in that community to help better understand the impact of the decisions we make on every project in every community.*

Amin Tehrani
North Texas Municipal Water District

How did you get started in the trenchless industry? *My first exposure to Trenchless Technology occurred during my PhD studies, when I had the opportunity to work with Dr. Mo Najafi and Dr. Ellie Kohankar at the University of Texas at Arlington. This experience opened a new door for me in the field of civil engineering. I was fascinated by how innovative and beneficial trenchless technology methods are in overcoming the challenges of pipeline installation and maintenance.*

Who inspires you and why? *In the trenchless technology industry, there are many people who inspire me, but one person who stands out is Chris Macey. He received the NASTT Hall of Fame Award in 2018 during the No-Dig Show in Chicago, which was also my first No-Dig event. I had the privilege of speaking with him right after he received the award, and over the years, I've had the opportunity to work with him on various committees. What has always impressed me about Chris is his incredible modesty and down-to-earth nature. Despite his many achievements, he remains humble and approachable, which I find truly inspiring.*

What career advice would you give to a young person? *Do not to be afraid of making mistakes. Mistakes are an essential part of learning and growth. Don't be discouraged if things don't work out perfectly the first time. Instead, see it as an opportunity to try different approaches and learn from the experience. The key is to keep experimenting, be curious, and keep searching for the right solution. The most important thing is to stay persistent and never stop learning.*

NORTH AMERICAN SOCIETY *FOR* TRENCHLESS TECHNOLOGY

TRENCHLESS TECHNOLOG

TYPICAL CRITERIA	HDD	Direct Steerable Pipe Thrusting	Microtunneling	Pilot Tube B
Pipe Diameter	2 - 48 inches	30 - 60 inches	30 - 120 inches	4 - 48 inche
Depth Range	15 - 200 feet	25 - 130 feet	15 - 100 feet	8 - 30 feet
Length Range	200 - >10,000 feet	500 - 4,000 feet	200 - 3,000 feet	50 -300 feet
Maximum Length	>10,000 feet	>5,000 feet (7,500 feet maximum)	2,000 feet with intermediate jacking stations	+/- 400 feet
Minimum Depth of Cover	>25 feet	As low as 2X pipe diameter	As low as 2X pipe diameter	As low as 4
Design Angles	Entry: 8 to 14 degrees / Exit: 8 to 16 degrees	Launch: 0 to 8 degrees / Reception: 2 to 10 degrees	Typically < 2.5%	Typically < 2
Entry/Launch Approach	Surface entry	Near surface launch	Shaft launch	Shaft launch
Min. Install Radii	Governed by installation & operating stresses	Governed by installation & operating stresses	Generally flat or sloped	Generally fla
Pit/Shaft Design	Shallow pit, non-engineered	Engineered shoring for shallow launch pit; shallow, non-engineered reception pit	Engineered shoring for launch & reception shaft	Engineered launch & re
Foundation	Traditional deadman	Engineered for site conditions & anticipated loads	Engineered for site conditions & anticipated loads	Engineered conditions & loads
Pipe Stringing	Typically exit side	Launch side	Pipe segment storage on launch side	Pipe segmen launch side
Installation Stresses	Tension, bending, hydrostatic buckling & combined	Compression, bending, & combined; column buckling	Compression & buckling	Compressio
Annular Pressures	Hydrostatic drilling fluid pressure & cutting transport pressure	Hydrostatic lubricating pressure & slurry over pressure	Hydrostatic lubricating pressure & slurry over pressure	Hydrostatic pressure
Gravel, Cobbles and Boulders	High risk of failure for > ~30-40% gravel	Can negotiate limited rocks up to 1/3 size of the cutterhead, and up to ~30 - 40% gravel	Can negotiate limited rocks up to 1/3 size of the cutterhead, and up to ~30 - 40% gravel	High risk of
Clay Soils	Risk of hydraulic fracture	Low risk of hydraulic fracture	Low risk of hydraulic fracture	Low risk of h fracture
Relative Cost	$$	$$$$	$$$$	$$

GY OVERVIEW GUIDE: NEW INSTALLATIONS

Guided Auger oring	Auger Boring	Pipe Ramming	Pipe Jacking	Hand Mining/ Tunneling
s	12-72 inches	12 - 120 inches	42 - 144 inches	42 - 144 inches
	8 - 30 feet	5 - 25 feet	10 - 40 feet	10 - 40 feet
t	50 - 300 feet	50 - 300 feet	200 - 1,000 feet	100 - 600 feet
:	+/- 500 feet w/ guidance	+/- 400 feet w/ guidance	1,500 feet with intermediate jacking stations	1,000+ feet
0-inches	As low as 2X pipe diameter	As low as 1X pipe diameter	As low as 2X pipe diameter	As low as 2X pipe diameter
.5%	Typically < 2.5%	Typically < 2.5%	Typically < 2.5%	Typically < 2.5%
n	Shaft launch	Shaft launch	Shaft launch	Shaft launch
at or sloped	Generally flat or sloped	Generally flat or sloped	Generally flat or sloped	Generally flat or sloped
shoring for ception shaft	Engineered shoring for launch & reception shaft	Engineered shoring for launch & reception shaft	Engineered shoring for launch & reception shaft	Engineered shoring for launch & reception shaft
for site & anticipated	Engineered for site conditions & anticipated loads	Engineered for site conditions & anticipated loads	Engineered for site conditions & anticipated loads	Engineered for site conditions & anticipated loads
nt storage on	Pipe segment storage on launch side	Pipe segment storage on launch side	Pipe segment storage on launch side	Tunnel liner segment storage on launch side
n & buckling	Compression & buckling	Compression & buckling	Compression & buckling	Compression & buckling
lubricating	Hydrostatic lubricating pressure	Hydrostatic lubricating pressure	Hydrostatic lubricating pressure	Hydrostatic lubricating pressure
failure	Can negotiate up to 1/3 size of the cutterhead	Casing can be sized to swallow up cobbles & boulders	Medium risk of failure. Can access tunnel heading for removal of obstructions	Medium risk of failure. Can access tunnel heading for removal of obstructions
hydraulic	Low risk of hydraulic fracture	Low risk of hydraulic fracture	Low risk of hydraulic fracture	Low risk of hydraulic fracture
	$	$$	$$$	$$$

North American Society for Trenchless Technology

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North American Society for Trenchless Technology (NASTT)

NASTT's 2024 No-Dig North

Niagara Falls, ON
October 28-30, 2024

WA-T1-03

Transforming Edmonton's Infrastructure: The 99 Avenue Sanitary Trunk Bypass Project

Vijayakumar Chinnathambi, P.Eng., PMP., IntPE., APEC Engineer, Project Manager, EPCOR, Edmonton, Alberta
Yang Bai, Project Manager, Shanghai Construction Group (Canada) Corporation, Edmonton, Alberta
Christopher Lamont, C.E.T., P.Eng., Associated Engineering, Edmonton, Alberta
Chris Jones, P.Eng., Team Lead, Stantec Consulting, Edmonton, Alberta

1. ABSTRACT

Canadian POTY *Abstract*- 99 Ave Sanitary Trunk Bypass

The 99 Avenue Sanitary Trunk Bypass project is a hallmark of modern infrastructure development, addressing the urgent need for the rehabilitation of a critical 1.1 km sanitary trunk sewer in Edmonton, Alberta. Spanning over three years, this two-stage project demonstrates EPCOR's commitment to innovation, environmental stewardship, and community engagement. The project involved the construction of a 1.6 km bypass sewer using advanced microtunneling technology, allowing for the safe rehabilitation of

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North American Society for Trenchless Technology (NASTT)
NASTT's 2024 No-Dig North

Niagara Falls, ON
October 28-30, 2024

WM-T2-03

Rehabilitating the Kenilworth Trunk Watermain

Gerald Bauer, Stantec Consulting Ltd., Ottawa, Ontario
Erez Allouche, Stantec Consulting Ltd., Edmonton, Alberta
Harry Krinas, City of Hamilton, Hamilton, Ontario
Joe Grieci, City of Hamilton, Hamilton, Ontario

1. ABSTRACT

The City of Hamilton's Kenilworth Transmission Main is a 1,050 mm diameter carbon steel watermain constructed in 1959 and 1960. It is one of two feeder mains that supply water to the Hamilton Mountain and is a critical link in the City's drinking water supply network. The alignment of this main includes a 250 m horizontal section and a 50 m vertical section along the Niagara Escarpment, both installed within a 2.7 m (9 ft) diameter concrete shaft/tunnel. Previous investigations noted significant deterioration consisting of rusting, corrosion, and pitting on the outside surface of the watermain. Nondestructive investigations of the watermain were completed in recent years including visual inspections, internal CCTV investigation and a Guided Wave Ultrasonic inspection, all of which identified deterioration and loss of wall thickness in some locations, including joint integrity and internal lining competence. In order to keep the infrastructure in reliable condition, the need for rehabilitation was identified. A trenchless renewal option assessment identified a viable cost-effective method to rehabilitate versus replace the existing watermain; this led to the design and tendering, then construction phases of the project. This paper focuses on the complexity of the deterioration and how the preferred rehabilitation option involving Carbon Fibre Reinforced Polymer was selected.

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North American Society for Trenchless Technology (NASTT)

NASTT's 2024 No-Dig North Show

Niagara Falls

October 29-30, 2024

Diagnose-Advise-Treat. A Process to Rehabilitate Manholes

Robert Epp, infraStruct Products and Services, Edmonton, AB

1. Abstract

Across the Country, manholes are aging and deteriorating at a rapid rate. Left unrepaired, at street level these manholes can cause safety concerns, vehicle damage, and potentially expensive and inconvenient replacement efforts. Below ground, damaged manholes can dilute sewage, increase sewage volumes, back up sewage and make wastewater treatments more inefficient. Bottom line, although an unseen asset from a public perspective the deteriorating manholes below play a very important role in ensuring the system remains operational.

To simplify the selection of the appropriate manhole rehabilitation method this presentation will break down the process into three categories, Diagnose, Advise and Treat (D.A.T.).

A **diagnosis** of the problem needs to be defined. Is the problem:

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North American Society for Trenchless Technology (NASTT)
NASTT's 2024 No-Dig North

Niagara Falls, ON
October 28-30, 2024

WM-T1-05

Direct Pipe® Provides Effective Solution for A Challenging Crossing in BC's Lower Mainland

Lawrence Onwude, M.Eng., P.Eng., Stantec Consulting Ltd., Edmonton, Alberta
Jake Fei, EIT, Stantec Consulting Ltd., Edmonton, Alberta
Trevor Miles, P.Eng., Universal Pegasus International, Calgary, Alberta
Erez Allouche, PhD., P.Eng., Stantec Consulting Ltd., Edmonton, Alberta

1. ABSTRACT

The Trans Mountain Expansion Project (TMEP) consists of 988 kilometres (613 miles) of new Nominal Pipe Size (NPS) 36 and NPS 42 pipeline, and 193 kilometres of NPS 24 reactivated pipeline. It twins the existing 1950s era Trans Mountain Pipeline (TMPL), through Alberta and British Columbia. TMEP utilized the Direct Pipe® methodology extensively for the British Columbia portion of the TMEP, and specifically in the expansive floodplain of British Columbia's Lower Mainland. Direct Pipe, a hybrid trenchless construction method that incorporates some of the advantages of Horizontal Directional Drilling (HDD) and microtunneling, offers an effective solution to crossings that feature highly restricted staging areas, complex geological conditions and/or multiple regulatory, permitting and environmental constraints. One such crossing was Construction Work Package 38 (CWP 38), involving the crossing of the CN mainline railway, a fish bearing water course and two archaeological sites in a single pass. Challenges included subsurface conditions, steep slopes, a tight workspace and an array of regulatory

SIXTH ANNUAL NO-DIG NORTH CONFERENCE 2024 IN NIAGARA FALLS A ROARING SUCCESS!

Underground Infrastructure Sustainability with Trenchless Technology in Canada

With the roar of beautiful Niagara Falls and autumn colours a fitting backdrop, the sixth annual No-Dig North Conference was another highly successful showcase of leading edge trenchless technology solutions. Over 1,000 delegates from across North America gathered together to enjoy a three days of networking and four tracks of peer-reviewed, presentations on New Installations and Rehabilitation providing the best trenchless solutions and cost-saving opportunities for municipalities and utilities.

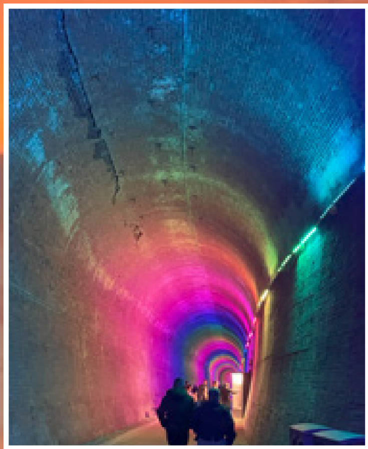
In addition to over 80 presentations from notable industry experts, the technical portion of the conference program also featured four NASTT Good Practices Courses on the first day and over 140 exhibits showcasing a wide range of trenchless and condition assessment technologies. There were abundant opportunities for networking and personal access to industry experts including a Welcome Reception in the Exhibit Hall. A cocktail reception and tour at the historic Niagara Falls Power Station, was a spectacular experience, with a 2,200-foot-long restored brick arch conveyance tunnel threading 180 feet deep under the Niagara Escarpment ending at an outdoor platform with a unique unforgettable view from the bottom of the Falls.

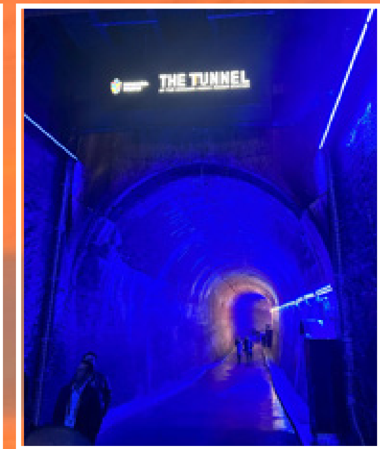
Student volunteers from Concordia University, Abdelhady Omar (left) and Shrouk Gharib (right)

Over 140 trenchless exhibits offered close-up personal access to industry experts


Conference registrations were quick and efficient – over 1,000 delegates passed through the doors of the Niagara Falls Convention Centre


NASTT staff helping behind the scenes, from l-r: Michelle Hill (Conference Services Director), Jessie Clevenger (Conference & Sales Director), Kari Webb, (Education Manager)





Cocktail reception and tour of historic Niagara Falls Power Station and Tunnel was a highlight of the conference

Congratulations to Conference Chair Ashley Rammeloo and Technical Program Chair Hiva Mahdavi for organizing such an informative and well-attended conference, showcasing Canada's trenchless expertise. The GLSLA, Northwest and British Columbia Chapters along with NASTT thank all attendees for their participation in a highly successful sixth annual 2024 No-Dig North. We wish to extend our appreciation to all our volunteers, presenters, moderators, and attendees for their participation, time and effort. A special note of thanks also goes out to our valued Sponsors & Exhibitors. We thank you for your support!

No-Dig North is the largest trenchless technology conference in Canada where municipalities, contractors, consulting engineers, public utilities, industrial facilities, and damage prevention professionals attend to learn new techniques that will save money and improve infrastructure. Aniticpating more success at the 7th Annual No-Dig North held in conjunction with the ISTT International No-Dig and Exhibition, October 28 – 30 in Vancouver BC. Another exciting can't-miss event for trenchless professionals!

Over 1,000 delegates enjoyed two full days of over 80 presentations from notable industry leaders

Ribbon cutting during Opening Breakfast, from l-r: Matthew Izzard (NASTT Executive Director), Ashley Rammeloo (Program Chair), Hiva Mahdavi (Technical Program Chair)

For information on NASTT 2025 NO-DIG NORTH & ISTT International No-Dig conference, October 28 – 30 in Vancouver BC, please visit:

https://nastt.org/no-dig-north

New Vermeer Autotension Feature Enhances Efficiency on Intersect Bores

Vermeer is enhancing the capabilities of the D220x500 S3 and D550 horizontal directional drills (HDDs) with the optional AutoTension feature that simplifies the connection of two drill rigs working on intersect bores. After completing a pilot bore, a drill outfitted with AutoTension allows HDDs on both sides of the bore to work together to increase the efficiency of reamer passes and the process of adding or removing drill rods to the tail string. When activated, AutoTension maintains a steady tension force on the drill string, helping to streamline large diameter and long-distance bores.

"The HDD industry is witnessing a growing trend of employing a drill rig on each side of a large diameter or long bore," explained Marv Klein, application specialist for Vermeer. "With Vermeer AutoTension on the D220x500 S3 and D550, crews on the entry and exit side of the bore can work together while reaming and swabbing a bore hole. This leads to more efficient and accurate reamer passes without the need for a mechanical locking swivel or breakout tongs for rod handling. Also, AutoTension helps optimize fluid management on the job because the need to transport fluids using vacs or pumps from one side to the other is reduced because crews can pull ream and pump fluids from either side."

The AutoTension feature, engaged from the control station, maintains a desired tension on the tail string throughout the drilling process. It allows for temporary disengagement when necessary – such as during rod additions or removals – without halting operations. This flexibility extends to directional changes, enabling the driving machine to switch between pushing and pulling without requiring action from the operator in the other drill.

The AutoTension feature also includes a lack of operator presence safety system. When the AutoTension operator leaves the seat, certain controls are locked out and an audible alert sounds at the AutoTension machine.

This innovative feature offers several key benefits to HDD crews. It optimizes reamer penetration through consistent tension

application and improves positioning and control of the reamer within the bore hole. Moreover, AutoTension helps maintain the intended bore path and reduces potential complications during the drilling process.
Contractors can match different Vermeer HDDs with the D220x500 S3 or D550 using AutoTension. Also, people who already own a D220x500 S3 or D550 can add this feature to their units. An authorized Vermeer dealer will need to help execute these upgrades.

For more information about the D220x500 S3 and D550 HDDs, contact your **local Vermeer dealer** or visit **vermeer.com**.

About Vermeer Corporation
Vermeer delivers a real impact on the way important work gets done through the manufacture of high-quality agricultural, underground construction, surface mining, tree care and environmental equipment. With a reputation for being built tough and built in a better way, Vermeer equipment is backed by localized customer service and support provided by independent dealers around the world. To learn more about Vermeer, products, the dealer network and financing options, visit vermeer.com.

HAMMERHEAD TRENCHLESS

HammerHead Trenchless Acquires ProKASRO Services USA

Acquisition expands product offering for the rehabilitation and replacement of lateral and mainline underground infrastructure

HammerHead Trenchless, a division of The Toro Company (NYSE: TTC), today announced that it has acquired the assets of ProKASRO Services USA, the distributor of ProKASRO Mechatronik GmbH and market leader of robotic solutions and rehabilitation equipment for repairing underground water and wastewater infrastructure. The terms of the transaction were not disclosed.

ProKASRO Services USA is known for its industry-leading robotics, UV pipe lining solutions and lateral rehabilitation technologies. Based in Centennial, Colorado, its expanded line of trenchless solutions enable utility contractors the ability to rehabilitate underground wastewater and water pipelines without the need for digging or disruption to outdoor environments.

"We are excited to announce the acquisition of ProKASRO Services USA," said Jeff Gabrielse, General Manager of HammerHead Trenchless. "This acquisition aligns with our strategic growth initiatives and helps expand our business into new markets with the leading technologies and brand reputation of ProKASRO. With the addition to the HammerHead Trenchless portfolio, we believe we are best positioned to offer a full suite of trenchless pipe rehabilitation and replacement products for contractors from laterals to mainlines in both the CIPP and pipe bursting markets."

Through this acquisition, HammerHead Trenchless will market these products under the ProKASRO USA brand name and serve the U.S. market with continued operations in Colorado. "With service facilities now in both Wisconsin and Colorado, HammerHead is positioned geographically to maintain customer expectations for quality and further expand the HammerHead legacy of customer service, support and innovation," said Gabrielse.

For more information on the full suite of HammerHead Trenchless products visit **www.hammerheadtrenchless.com**

About HammerHead Trenchless

HammerHead Trenchless, a division of The Toro Company, manufactures and delivers a unique combination of rehabilitation, replacement and installation equipment and consumables for the underground construction market. Besides being a full solutions provider in rehabilitation and replacement, HammerHead also offers unmatched field support and project consultation to its customers worldwide. HammerHead products are proudly made in the U.S.A. and sold and serviced in more than 60 countries. For more information visit **www.hammerheadtrenchless.com**; 920-648-4848

About The Toro Company

The Toro Company (NYSE: TTC) is a leading global provider of solutions for the outdoor environment including turf and landscape maintenance, snow and ice management, underground utility construction, rental and specialty construction, and irrigation and outdoor lighting solutions. With net sales of $4.6 billion in fiscal 2024, The Toro Company's global presence extends to more than 125 countries through a family of brands that includes Toro, Ditch Witch, Exmark, Spartan, BOSS, Ventrac, American Augers, Trencor, Subsite, HammerHead, Radius, Perrot, Hayter, Unique Lighting Systems, Irritrol, and Lawn-Boy. Through constant innovation and caring relationships built on trust and integrity, The Toro Company and its family of brands have built a legacy of excellence by helping customers work on golf courses, sports fields, construction sites, public green spaces, commercial and residential properties and agricultural operations. For more information, visit **www.thetorocompany.com**.

Mid-State Hydrovac Relies on Guzzler Guzzcavators

Leonel Oviedo and his father began Mid-State Hydrovac in 2017. The idea began after they worked for a roofing contractor and saw the work it took to remove gravel off of commercial roofs.

In that first year they bought a Guzzler Guzzcavator – a dual purpose industrial vacuum loader and hydroexcavator. Two years later they bought another, and they have bought one every single year since then.

"Guzzlers have a good balance," said Leonel Oviedo, owner and business development, Mid-State Hydrovac. "You can look at the machines and the technology, and you know they're operating more efficiently. That's the beauty of these trucks. Your imagination is the only thing holding you back."

Oviedo has been in charge of purchasing decisions since the start while his dad handles job assignments for their team of 11 people. They use their Guzzler trucks to remove roof rock, hydroexcavation, concrete plants, graphite plants and anything else that can't be removed by conventional means.

"We stick with Guzzler because of their versatility, and we use a Kenworth or International chassis," said Oviedo. "The versatility of the Guzzler allows us the liberty of pricing jobs comfortably because we can literally do anything. We focus on doing the job properly and that final product."

That mentality of focusing on quality is what keeps Mid-State Hydrovac busy. Oviedo said they want to keep that up as they look ahead to the next five years.

"We try to highlight that we're a jack of all trades," said Oviedo. "We have a lot of experience and we're able to do a lot with these trucks. Versatility is how we do it. We don't just send a truck and two people. We send in the right amount of people. The customer points and we do."

Mid-State Hydrovac currently handles around nine jobs a week. With that workload, reliability is essential. Oviedo works with Guzzler Regional Sales Manager Ted Cobb who Oviedo said "goes above and beyond and understands our hands-on experience."

That relationship and direct connection is important as Mid-State Hydrovac customizes its Guzzcavators for its specific needs. For example, Mid-State uses a 1300-gallon water tank, a showroom blue chassis and a port that is accessible from the back. It also uses a water pump that is 10 gallons per minute instead of 20 in order to conserve water on hydroexcavation jobs.

"The Guzzlers are some of the most forgiving pieces of equipment we own. We try our best to maintain them and do the proper maintenance, and it's helpful that they are such reliable pieces of equipment," said Oviedo.

About Guzzler

Guzzler is the leader in mobile vacuum solutions. For more than 40 years, Guzzler has supplied industrial and utility customers with a wide range of vacuum equipment built with the user in mind. From its manufacturing facility in Streator, Illinois, Guzzler innovates solutions that help customers increase productivity.

Disaster Relief in Fort Lauderdale With Primus Line's Flexible Pipe

Floods, landslides, tornados, wildfires – news of natural disasters seems to be on the rise. What to do when such a catastrophe damages the water infrastructure and you, as a network operator, have to restore the drinking water supply?

For the construction of bypasses or emergency pipelines, Rädlinger Primus Line have two different products in their portfolio: Primus Line® Rehab and Primus Line® Overland Piping. While the latter is specifically designed for the temporary above-ground transport of fluids and reusable, the former is normally used for the rehabilitation of pressure pipelines. However, both can be applied for disaster relief, as their three-layer composition – the middle layer is made of Kevlar® fabric – ensures flexibility, stability and safety in combination with the special connectors.
To ensure sustainable drinking water and firefighting capabilities in the event of a natural disaster, the City of Fort Lauderdale was looking for equipment that could quickly repair any breaks in its drinking water mains or sewer force mains. In 2018, the City of Fort Lauderdale embarked on a groundbreaking project. In coordination with the Rädlinger Primus Line engineering team and the city's engineers, the concept of the rapid response kit was realised – a unique solution.

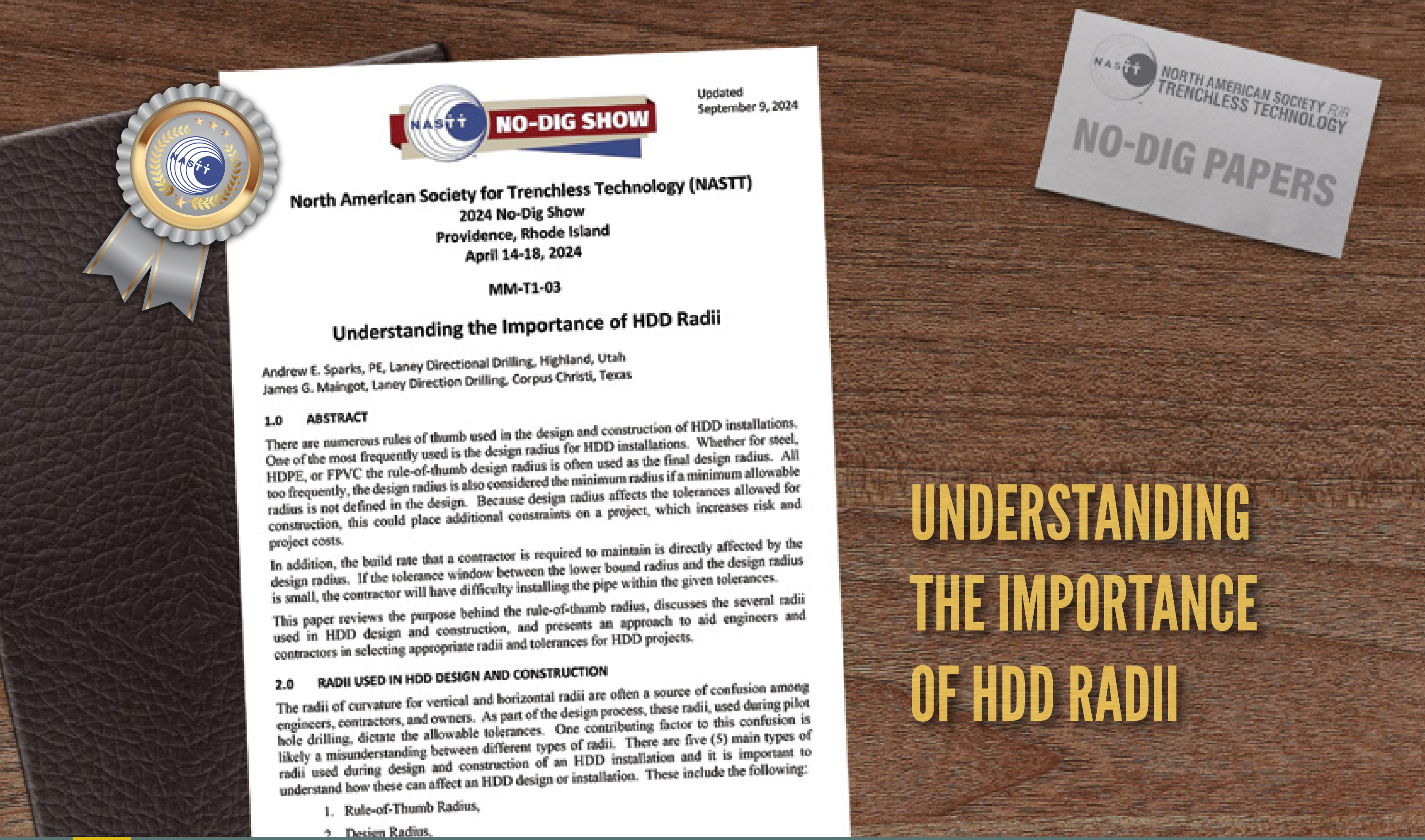
The container with the FFRP equipment in Fort Lauderdale can easily be transported on a truck

People in the southeastern United States are used to disaster situations, especially during hurricane season. In order to maintain the water supply in such cases, Rädlinger Primus Line delivered the first two "Pipeline Rapid Response Kits" (PRRK) to Fort Lauderdale in July 2019. The two 12-metre/40-foot containers – one for drinking water and one for wastewater – hold two or three reels of rolled up Primus Liners and customised flange adapters of various sizes, at least two of each type.

These PRRKs are the fallback strategy for catastrophic situations such as hurricanes or floods, which is reassuring for those responsible for dealing with major pipeline breaks in Fort Lauderdale. The PRRKs allow the city's emergency response crew to bypass pipe breaks in almost inaccessible locations. Customised adapters for different pipe sizes (DN 800 to DN 1500, corresponding to sizes of 30 to 54 inches) and flexible DN 500/20-inch Primus Liners with a single length of 426 metres/1,400 feet per reel serve as temporary bypasses. For example, three DN 500/20-inch Primus Liners can be combined to keep up the water supply of a broken DN 1200/48-inch pipe in emergency situations and can be run at pressures of up to 16 bar/230 psi.

In some situations, opening the damaged line at two easily accessible points, rather than trying to repair it directly at the site of incident under extreme time pressure, may be the decisive factor.

In order to be optimally prepared for such catastrophic situations with the PRRKs, the Fort Lauderdale emergency response crew spent two days training in the use and application of the Primus Liners and their adapters. Everything they need is packed in the two containers, which can be easily transported to the affected area. In addition, the entire kit can be reused for the next emergency situation.



UNDERSTANDING THE IMPORTANCE OF HDD RADII

AUTHORS

Andrew E. Sparks, PE,
Laney Directional Drilling,
Highland, Utah

James G. Maingot
Laney Direction Drilling,
Corpus Christi, Texas

1.0 ABSTRACT

There are numerous rules of thumb used in the design and construction of HDD installations. One of the most frequently used is the design radius for HDD installations. Whether for steel, HDPE, or FPVC the rule-of-thumb design radius is often used as the final design radius. All too frequently, the design radius is also considered the minimum radius if a minimum allowable radius is not defined in the design. Because design radius affects the tolerances allowed for construction, this could place additional constraints on a project, which increases risk and project costs.

In addition, the build rate that a contractor is required to maintain is directly affected by the design radius. If the tolerance window between the lower bound radius and the design radius is small, the contractor will have difficulty installing the pipe within the given tolerances.

> **This paper was selected as Outstanding Paper of the Year – New Installations from all the presentations at the 2024 NASTT No-Dig Show in Providence RI.**
>
> **NASTT No-Dig Papers are available for download, free to members, at www.nastt.org**

This paper reviews the purpose behind the rule-of-thumb radius, discusses the several radii used in HDD design and construction, and presents an approach to aid engineers and contractors in selecting appropriate radii and tolerances for HDD projects.

2.0 RADII USED IN HDD DESIGN AND CONSTRUCTION

The radii of curvature for vertical and horizontal radii are often a source of confusion among engineers, contractors, and owners. As part of the design process, these radii, used during pilot hole drilling, dictate the allowable tolerances. One contributing factor to this confusion is likely a misunderstanding between different types of radii. There are five (5) main types of radii used during design and construction of an HDD installation and it is important to understand how these can affect an HDD design or installation. These include the following:

1. Rule-of-Thumb Radius,
2. Design Radius,
3. Minimum Allowable Radius,
4. Lower Bound Radius, and
5. Failure Radius.

These radii play an important role in the successful design and installation of pipelines using the HDD installation method. They are illustrated in Figure 1 and discussed in detail in the following sections.

2.1 Rule-Of-Thumb Radius

The most common radius used in HDD design and construction is the rule-of-thumb radius (R_{rt}). The radius emerged from the early years of HDD construction following several pipe failures and offered a simplified method to estimate a radius that would yield a safe radius of curvature for steel pipe with a diameter to thickness ratio less than about 60 (PRCI 2015). This rule-of-thumb radius is supported by stress calculations that will generally yield an HDD design that will not overstress the pipe under typical installation and operating conditions.

The rule-of-thumb radius is commonly used in preliminary HDD design and unfortunately often continues from conceptual design to final design without considering reasons for adjustment for an optimized design.

2.2 Design Radius

After the preliminary HDD design has been completed with radii based on the rule-of-thumb radius, the engineer should optimize the design based on site limitations, subsurface conditions, and final pipe properties. The design radius (R_d) should be as large as possible and still facilitate good geometric design and reduce construction difficulty. The design radius can be different than the rule-of-thumb radius depending on site conditions and pipe property limitations and should be a primary consideration when establishing the tolerance window for each HDD installation.

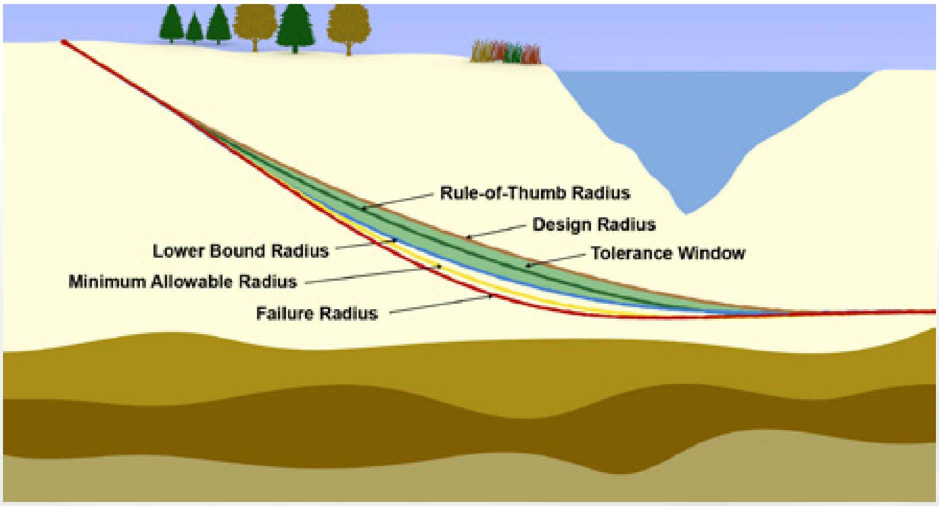


Figure 1. Radii of Curvature for HDD Design

In practice, the rule-of-thumb radius is used as the design radius in most HDD designs. Doing so without considering the implications can, in many instances, increase construction costs and risk. The design radii of curvature should also consider the potential steering difficulties that could be experienced during construction. If the subsurface conditions indicate that steering difficulties could be experienced, the radii should be increased as much as possible to provide a large tolerance window between the design radii and the lower bound radii. A larger window will make it more likely to complete the pilot hole and remain within tolerance.

An additional benefit of designing the largest radius possible is the increase of weight on the drill bit. Larger radii allow a greater amount of the force applied by the drill rig to be transferred along the drill pipe to the drill bit. Smaller radii reduce the amount of force transferred to the drill bit.

2.3 Minimum Allowable Radius

The minimum allowable radius (R_{ma}) of curvature is the smallest radius a pipe should experience at any time during construction or operation. It is determined based on the pipe properties, internal operating pressures, external loads, and appropriate factors of safety/design factor.

The minimum allowable radius is often used as the lower limit of the tolerance window for construction. However, if during pilot hole drilling, the as-built radius is smaller than the R_{ma}, an owner or a permitting agency could require an HDD contractor to redrill th e pilot hole or spend time and effort resizing the hole to increase the as-built radius. As a result, the R_{ma} is not recommended for use as the lower tolerance window limit.

2.4 Lower Bound Radius

A more appropriate option may be to establish a lower bound radius (R_{lb}) as the lower tolerance limit. This is selected by the engineer during the design process based on pipe diameter, pipe properties, subsurface conditions, and anticipated drilling difficulty. The R_{lb} is larger than the R_{ma} to provide an additional steering tolerance to the tolerance window and to reduce the risk of approaching or exceeding the R_{ma}. The engineer should select a lower bound radius that provides an adequate tolerance window and still allows for uncertainties during pilot hole drilling.

2.5 Failure Radius

The failure radius (R_f)) is the smallest radius the pipe can withstand before plastic deformation occurs. If this radius is achieved, the pipe would be at the threshold limit where collapse, buckling, or plastic bending is imminent. The failure radius does not include a factor of safety. Understanding this radius can be especially important during pipe installation where pipe buckling could occur in the overbend when insufficient pipe handling equipment is used, or care is not taken when placing the pipe in the overbend, see Figure 2.

Figure 2. Plastic Bending of Steel Pipe at the Failure Radius

3.0 RADIUS CALCULATIONS

3.1 Steel Pipe

For steel pipe, the rule-of-thumb radius measured in feet is calculated by multiplying the outside diameter of the pipe in inches, by 100, see Equation 1. It is also common to multiply the outside diameter of the pipe in inches by 1,200 but yields a radius in inches. Because the rule-of-thumb radius is a simplification and is not based on the pipe properties or site conditions, it should only be used in preliminary design.

$$R_{rt} = D_0 \cdot 100 \qquad [1]$$

Where:

R_{rt}	=	Rule-of-thumb Radius, feet
D_o	=	Outside Diameter of Steel Pipe, inches

The calculation of the minimum allowable radius (R_{ma}) for steel pipe is presented in Section 5.2.2 of the Pipeline Research Council International (PRCI) engineering design guide (PRCI 2015) and is shown in Equation 2. The calculation includes a factor of safety in the form of the design factor. The design factor is determined by the type of product the pipeline will carry and the site location (CFR Part 192 and CFR Part 195).

$$R_{ma} = \frac{E \cdot D_O}{2 \cdot f_b \cdot DF} \qquad [2]$$

Where:

R_{ma}	=	Minimum Allowable Radius
E	=	Modulus of Elasticity for Steel
D_o	=	Outside Diameter of Steel Pipe
f_b	=	Longitudinal Stress from Bending
DF	=	Design Factor

The minimum allowable radius should never be exceeded during construction and could result in increased project costs and delays if exceeded. Pipe stresses are typically calculated using the R_{ma} to evaluate maximum anticipated stresses during installation and under operating conditions and should not be exceeded by the as-built radius.

The failure radius (Rf) is the same calculation as Equations 2 but does not include a factor of safety (design factor) and the bending stress is equal to the yield stress. It is used primarily as the lower limit to which a pipe can be subjected before plastic deformation occurs.

3.2 HDPE Pipe

Because HDPE is more elastic than steel, the rule-of-thumb radius for HDD design for steel pipe does not apply. The design radius is typically controlled by the minimum bending radius of the drill pipe used for the HDD installation and not by the product pipe. In addition, drilling curves as small as the minimum radii for drill pipe should be avoided because wear and cyclic loading reduce the effective minimum radius of drill pipe.

Consideration should also be given to the minimum radius through which the proposed tooling can be pulled during reaming operations. For large diameter HDPE pipe where large tooling is required, this often results in design radii similar to those typically designed for steel pipe.

Based on the Handbook of Polyethylene Pipe by Plastic Pipe Institute (PPI), the minimum allowable radius (R_{ma}) in feet is 25 times the nominal outside diameter in feet (PPI 2008) or 2.1 times the outside diameter in inches. The PPI also recommends a lower bound radius (R_{lb}) in feet for HDPE approximately 40 to 50 times the nominal outside diameter in feet (3.3 to 4.2 times the diameter in inches). The PPI does not publish the failure radius (R_f), but because of its flexibility, the failure radius for HDPE is rarely approached.

3.3 Fusible PVC Pipe

HDD installations with Fusible PVC pipe can be generally designed with smaller radii than what is required for steel pipe. However, the design bend radius is typically controlled by the allowable radius of the drill pipe or tooling, except for the largest diameters of FPVC pipe. As a result, the design radii are often similar to those typically designed for steel pipe.

The Handbook of PVC Pipe published by Uni-Bell indicates that the R_{ma} in feet for FPVC pipe is approximately 250 times the outside pipe diameter in feet or 20.8 times the outside diameter in inches (Uni-bell 2012). The R_{ma} includes a standard factor of safety of 2.5 and an allowable bending stress of 800 psi. Removing the applied factors of safety, the R_f in feet is approximately 100 times the outside diameter in feet or 8.3 times the outside diameter in inches.

4.0 TOLERANCE WINDOWS

During HDD installation, the pilot hole cannot be drilled precisely along the design profile. There is always some variance between the as-built profile and the design profile. Regardless of the pipe material, the design must include an adequate tolerance window through which the HDD contractor can work, especially when drilling the curves. This tolerance window allows the HDD contractor the ability to steer with a slightly smaller radius than the design without concern for overstressing the pipe. If this window is too small, it will be difficult or impossible to install the product pipe in accordance with project requirements.

The difference between the lower bound radius and the design radius is defined as the tolerance window, see Equation 3. The tolerance window should be sufficiently large to allow the HDD contractor to steer the pilot hole without approaching the limits of the minimum allowable radius, R_{ma}. If the tolerance window is too small, the HDD contractor will not be able to make steering adjustments to steer back to the design profile without exceeding the R_{ma} limits. If the allowable radius is established at the R_{lb} instead of the R_{ma}, the HDD contractor can drill the radius as small as the R_{lb} without concern the pipe will be overstressed.

$$R_t = R_d - R_{lb} \qquad [3]$$

Where:

R_t	=	Tolerance Window
R_d	=	Design Radius
R_{lb}	=	Lower Bound Radius

4.1 Build Rate And Build Rate Tolerance

During pilot hole drilling, the HDD contractor steers along curved sections in terms of degrees of angle per length of drill pipe. This is commonly called the Build Angle or more appropriately, Built Rate because it is used in units of degrees per specified length, usually the number of joints of pipe. Typical build rates are measured over three joints of Range 2 pipe, which measures about 94.5 feet in length. For drill pipe joints used in smaller drill rigs, the build rate is calculated over a length of approximately 100 feet.

The larger the radius, the fewer degrees of steering per joint are required to maintain the design curve. This is shown in Equation 4, where the degrees of build angle are inversely proportional to the radius. Thus, larger radii require less steering, are easier to drill, and reduce the risk of exceeding tolerances.

$$\theta = \frac{lp}{r} \cdot \frac{180}{\pi} \qquad [4]$$

Where:

θ	=	Build Rate, degrees
l_p	=	Arc Length of Pipe Segment, feet (one joint or three joints)
r	=	Radius of Curvature, feet (design radius or lower bound radius)

While it is important to establish large enough radii to facilitate pilot hole drilling, it is equally important to establish a large enough tolerance window relative to the design radius in order to successfully complete the pilot hole. It should be noted that a tolerance window for a relatively large design radius is much different, in terms of constructability, than the same tolerance window for a small design radius.

The effective size of the tolerance window is illustrated by calculating the Build Rate Tolerance (BRT) as shown in Equation 5. The BRT is used to evaluate the size of the window with respect to the design radius, lower bound radius, and difference in build angle for a given number of joints of drill pipe.

$$\theta_{brt} = \theta_{lb} - \theta_d \qquad [5]$$

Where:

θ_{brt}	=	Build Rate Tolerance, degrees
θ_{lb}	=	Lower Bound Build Rate, degrees
θ_d	=	Design Build Rate, degrees

The BRT is the number of degrees of steering tolerance between the design radius and the lower bound radius. A small BRT only allows for small steering adjustments to maintain the pilot hole within tolerance and increases the risk of being out of tolerance during pilot hole drilling. A large BRT will allow larger steering adjustments to stay within tolerance and decreases the risk of being out of tolerance.

To provide adequate flexibility to drill the pilot hole without increased risk of being outside tolerances, the three-joint BRT should be as large as possible, but not less than about 1 degree and the one-joint BRT should not be less than about 0.33 degrees.

The three cases discussed below and illustrated in Table 1 show the BRT for 12-inch, 24-inch, and 36-inch diameter steel pipe. The tolerance window for all three cases is 600 feet, but each yield a significantly different BRT.

Table 1. Example Built Rate Tolerances

Radius Type	Case 1 – 12-inch-diameter Steel	Case 2 – 24-inch-Diameter Steel	Case 3 – 36-inch-Diameter Steel
Rule-of-Thumb Radius [1]	1,200 ft	2,400 ft	3,600 ft
Design Radius [2]	1,400 ft	2,400 ft	3,600 ft
Lower Bound Radius [3]	800 ft	1,800 ft	3,000 ft
Minimum Allowable Radius [4]	531 ft	1,310 ft	2,567 ft
Failure Radius [5]	242 ft	531 ft	880 ft
Tolerance Window [6]	600 ft	600 ft	600 ft
Build Rate for Design Radius [7]	3.87°	2.26°	1.50°
Build Rate for Lower Bound Radius [7]	6.77°	3.01°	1.80°
Three-Joint Build Rate Tolerance, degrees/3 joints [8]	2.90°	0.75°	0.30°
One-Joint Build Rate Tolerance, degrees/1 joint [9]	0.97°	0.25°	0.10°

Notes: 1. Radius is 100 · Diameter (in). Assumes 0.500-inch wall thickness, 1,440 psi maximum pressure, and grade 65 steel
2. Design radius selected based on site conditions, required geometry, and pipe properties.
3. Selected to maximize the tolerance window while still being greater than the minimum allowable radius.
4. Assumes Design Factor is 0.5 (FS=2).
5. No Design Factor included.
6. Design Radius – Lower Bound Radius.
7. Number of degrees per three joints (approximately 100 feet of Range 2 pipe) needed to turn the radius.
8. Three-Joint build rate tolerance is the difference between the design and lower bound build rate over three joints. Should be large enough to provide a three-joint build rate tolerance of 1 degree or larger.
9. One-Joint build rate tolerance is the difference between the design and lower bound build rate over one joint. Should be large enough to provide a one-joint build rate tolerance greater than about 0.33 degrees.

4.1.1 Case 1 – 12-inch-diameter steel pipe

The design radius for the 12-inch-diameter steel pipe is 1,400 feet and the lower bound radius is 800 feet, yielding a tolerance window of 600 feet. The build rate over the 100 feet of three joints is 3.87 degrees for the design radius and 6.77 degrees for the lower bound radius, yielding a build rate tolerance of 2.9 degrees. This allows approximately 3 degrees of steering tolerance over 100 feet between the design and lower bound radii. Three degrees of steering tolerance is sufficient for drilling a pilot hole.

4.1.2 Case 2 – 24-inch-diameter steel pipe

The design radius for the 24-inch-diameter steel pipe is 2,400 feet and the lower bound radius is 1,800 feet, yielding a tolerance window of 600 feet. The build rate over the 100 feet of three joints is 2.26 degrees for the design radius and 3.01 degrees for the lower bound radius, yielding a build rate tolerance of 0.75 degrees. This allows approximately 0.75 degrees of steering tolerance over 100 feet between the design and lower bound radii. This is less than the recommended 1 degree, even though the tolerance window is the same as for Case 1.

4.1.3 Case 3 – 36-inch-diameter steel pipe

The design radius for the 36-inch-diameter steel pipe is 3,600 feet and the lower bound radius is 3,000 feet, yielding a tolerance window of 600 feet. The build rate over the 100 feet of three joints is 1.50 degrees for the design radius and 1.80 degrees for the lower bound radius, yielding a build rate tolerance of 0.3 degrees. This allows approximately 0.3 degrees of steering tolerance over 100 feet between the design and lower bound radii and only 0.1 degree of steering tolerance per joint for the pilot hole, which is very difficult to achieve.

5.0 COMPOUND RADIUS

Most HDD installations are designed with only vertical radii. In some cases where site conditions require, a horizontal curve is introduced into the design. The horizontal curve is typically placed in the bottom tangent of the design with appropriate distances between vertical and horizontal curves so HDD contractors can effectively transition from a vertical curve to a horizontal curve. In rare cases where there is not enough space to separate the horizontal and vertical curves, the two curves must be designed to overlap, creating a compound curve.

Compound curves have become more common in the last 10 years but also add additional complexity and risk. Steering in three dimensions increases the risk of exceeding allowable radius tolerances, especially if the pilot hole surveyor is not experienced in steering compound curves. When possible, compound curves should be avoided to reduce the risk of construction difficulties.

When a compound radius curve is required, the compound radius controls when considering design radius, lower bound radius, the tolerance window, and BRT. If the compound radius is not considered when developing the tolerance window, the minimum allowable radius based on the pipe properties could be greater than the compound radius, thus making the HDD installation impossible without exceeding the allowable pipe stresses. The compound radius for combined horizontal and vertical curves can be calculated using Equation 6.

$$r_c = \sqrt{\frac{{r_v}^2 \cdot {r_h}^2}{{r_v}^2 + {r_h}^2}} \qquad [6]$$

Where:

r_c = Compound radius

r_v = Vertical radius

r_h = Horizontal Radius

6.0 BUNDLES

Small diameter pipelines and conduits are often installed in the same drilled hole in a bundle configuration to reduce construction costs and permitting difficulties. There are some unique issues involved with designing bundles installed by HDD, one of which is how to design the radii. The radii could be designed for the largest pipe or conduit diameter because smaller pipes would experience less bending stress; however, attention should be given to the flexibility of the tooling required to ream the hole to the final diameter.

For example, a bundle of four 8-inch-diameter steel pipes could be designed to a radius of 800 feet and not overstress the pipes. However, the final, reamed hole diameter might be 24 inches to accommodate the bundle. The tooling to create a 24-inch-diameter hole might not be flexible enough to pass efficiently along a radius of 800 feet, resulting in stuck tooling or an improperly conditioned hole.

It is recommended that engineers consult with an HDD contractor to understand the radii to which required tooling can be subjected. This will aid in selecting appropriate design radii for bundled HDD installations.

7.0 EXAMPLES

The following design examples illustrate the difference between an HDD installation for three design radii and how they can affect the constructability of an HDD. All three examples are based on a 24-inch-diameter steel pipe with the same properties. The relevant properties and parameters are shown in Table 2. Details of the radii and tolerances for each example are shown in Table 3.

7.1 Example 1

Example 1 represents a typical HDD design based on current standards of practice. The design radius (R_d) is equal to the rule-of-thumb radius of 2,400 feet and the lower bound radius (R_{lb}) is equal to 1,500 feet, which is near the minimum allowable radius (R_{ma}) of 1,477 feet. These radii provide a tolerance window of 900 feet and a build rate tolerance of 1.35 degrees over three joints.

This design provides an adequate tolerance window and BRT; however, the R_{lb} is very close to the R_{ma}. If an HDD contractor were to inadvertently drill the

Table 2. Properties and Parameters for Examples

Pipe Data	Design Parameter
Pipe Outside Diameter	24.00 inches
Pipe Wall Thickness	0.500 inch
Grade	X60 API 5L Steel
Maximum Allowable Operating Pressure	1,440 psi
Design Factor [1]	0.50 for Class 3
Rule-of-Thumb Radius [2]	2,400 ft
Minimum Allowable Radius [3]	1,477 ft
Failure Radius [4]	584 ft

Notes: 1. Design Factor and Class by CFR Title 49, Part 192.111 for gas pipelines
2. Radius is 100 · Diameter (in).
3. Calculated from PRCI Section 5.2.2 and 0.50 Design Factor.
4. No Design Factor included.

pile hole with a radius too small, the limit established by the R_{ma} could be exceeded, requiring time and effort to correct the tolerance break.

7.2 Example 2

Example 2 represents an HDD design intent to provide a steering buffer between the R_{ma} and the R_{lb} to allow the contractor to drill the curve near the R_{lb} with less concern with inadvertently breaking the lower tolerance limit, R_{ma}. The details of the radii and tolerances are also shown in Table 3.

The design radius (R_d) is equal to the rule-of-thumb radius of 2,400 feet and the lower bound radius (R_{lb}) is 1,800 feet, which provides an additional 300 feet of steering tolerance between the R_{lb} and the R_{ma}. These radii provide a tolerance window of 600 feet and a build rate tolerance of 0.75 degrees over three joints.

This design provides the additional steering buffer for the contractor, but also a smaller tolerance window and BRT. This would force the contractor into a small window with little ability to steer within the tolerance window.

7.3 Example 3

Example 3 represents an HDD design intent to provide a steering buffer but also an adequately large tolerance window and BRT. The details of the radii and tolerances are also shown in Table 3.

The design radius (R_d) is enlarged to 2,800 feet and the lower bound radius (R_{lb}) is equal to 1,800 feet, which provides a tolerance window of 1,000 feet and a build rate tolerance of 1.07 degrees over three joints. It also provides the 300 feet of steering tolerance between the R_{lb} and the R_{ma}.

This design not only provides a larger tolerance window and BRT, compared to Example 2, but also an additional steering buffer for the contractor. This allows a contractor a larger window to steer within the tolerance window.

These examples indicate that where there is flexibility in design, providing the largest tolerance window and BRT possible can significantly lower risk and decrease costs to a project. Understanding how the radius tolerance window and BRT of an HDD can affect the constructability of a project and is an important factor to consider during HDD design.

8.0 Recommendations For Practitioners

During the preliminary and final HDD design process it is important for practitioners to consider the several types of radii and how they can affect the constructability of an HDD installation. The final HDD design should not include radii based solely on the rule-of-thumb radius and should be designed to provide adequate tolerance windows and built rate tolerances to facilitate construction. Doing so can significantly lower risk and decrease project costs. On long crossings, practitioners should also design an HDD with the largest radii possible to transfer the largest amount of the force from the drill rig to the drill bit.

It is often tempting to introduce a compound horizontal and vertical curve into an HDD design. While it is possible to drill the pilot hole in a compound curve, it increases the complexity and the risk of breaking tolerances and damaging the pipe. Practitioners should only consider designing compound curves when there is no other option and even then, they should try to reduce the complexity as much as possible.

Additional consideration should also be given to the minimum radius through which the proposed tooling can be pulled during reaming operations. This is especially important when designing for HDPE or bundled pipes. Whether designing an HDD for steel, HDPE, or FPVC, practitioners should consider optimizing the design radii and establishing large tolerance windows and build rate tolerances to reduce complexity and increase the likelihood an HDD can be installed within project tolerances.

Table 3. Example Results

Radius Type	Example 1	Example 2	Example 3
Rule-of-Thumb Radius	2,400 ft	2,400 ft	2,400 ft
Design Radius	2,400 ft	2,400 ft	2,800 ft
Lower Bound Radius	1,500 ft	1,800 ft	1,800 ft
Minimum Allowable Radius	1,477 ft	1,477 ft	1,477 ft
Tolerance Window	900 ft	600 ft	1,000 ft
Build Angle for Design Radius [1]	2.26°	2.26°	1.93°
Build Angle for Lower Bound Radius [1]	3.61°	3.01°	3.01°
Three-Joint Build Rate Tolerance, degrees/3 joints [2]	1.35°	0.75°	1.07°
One-Joint Build Rate Tolerance, degrees/1 joint [3]	0.45°	0.25°	0.36°

Notes: 1. Number of degrees per three joints (approximately 100 feet of Range 2 pipe) needed to turn the radius.
2. Three-Joint build rate tolerance is the difference between the design and lower bound build rate over three joints. Should be large enough to provide a three-joint build rate tolerance of 1 degree or larger.
3. One-Joint build rate tolerance is the difference between the design and lower bound build rate over one joint. Should be large enough to provide a one-joint build rate tolerance greater than about 0.33 degrees.

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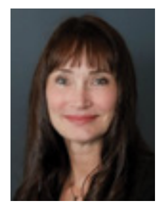

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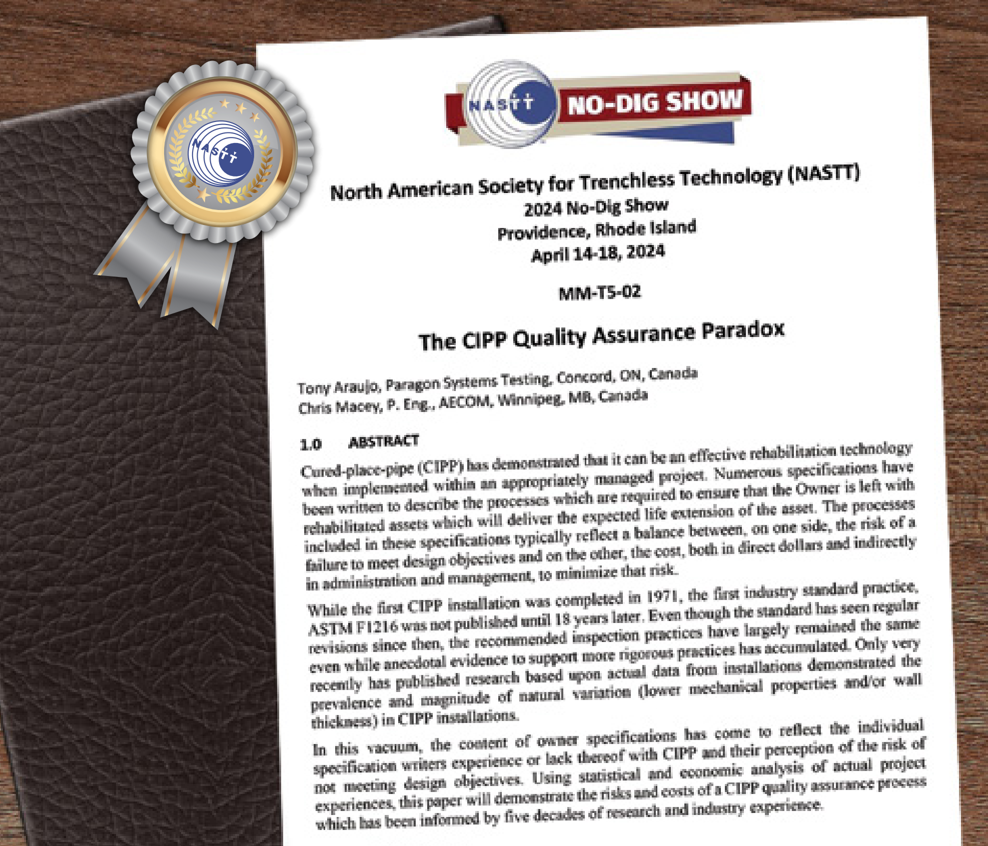
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The CIPP Quality Assurance Paradox

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1.0 ABSTRACT

Cured-place-pipe (CIPP) has demonstrated that it can be an effective rehabilitation technology when implemented within an appropriately managed project. Numerous specifications have been written to describe the processes which are required to ensure that the Owner is left with rehabilitated assets which will deliver the expected life extension of the asset. The processes included in these specifications typically reflect a balance between, on one side, the risk of a failure to meet design objectives and on the other, the cost, both in direct dollars and indirectly in administration and management, to minimize that risk.

While the first CIPP installation was completed in 1971, the first industry standard practice, ASTM F1216 was not published until 18 years later. Even though the standard has seen regular revisions since then, the recommended inspection practices have largely remained the same even while anecdotal evidence to support more rigorous practices has accumulated. Only very recently has published research based upon actual data from installations demonstrated the prevalence and magnitude of natural variation (lower mechanical properties and/or wall thickness) in CIPP installations.

In this vacuum, the content of owner specifications has come to reflect the individual specification writers experience or lack thereof with CIPP and their perception of the risk of not meeting design objectives. Using statistical and economic analysis of actual project experiences, this paper will demonstrate the risks and costs of a CIPP quality assurance process which has been informed by five decades of research and industry experience.

THE CIPP QUALITY ASSURANCE PARADOX

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2.0 INTRODUCTION

Short-term flexural properties flexural modulus and flexural strength are key design parameters for CIPP (Araujo et al 2010). Unlike traditional pipe materials which arrive on a job site with their minimum physical and dimensional properties already established, the final physical properties and wall thickness of CIPP cannot be determined to the same degree of certainty until after the installation has been completed and the installation acceptance tested (Braun & Macey 2021).

A feature of CIPP liners is the ability of the installer to choose from a myriad of resin/reinforcement systems, many of which are capable of achieving much greater physical properties than the minimums defined by the commonly used CIPP standard practices ASTM F1216 and F1743. Owner specifications commonly permit installers to utilize these higher properties to design thinner liners than would result if the liner was designed using only the ASTM minimum physical properties (Araujo & Yao, 2019).

Research has shown that installed flexural properties and wall thickness of CIPP, not infrequently are less than specified (Macey & Zurek, 2012), (Pharand & Rancourt 2015), (Araujo & Yao 2019), (Allouche et al 2014), (Waniek et al 2020). This phenomenon is inherent in the installation process for CIPP heat cured liners and has been referred to as natural variation (Braun & Macey 2021). While earlier research has highlighted individual examples of this variation (Allouche et al 2014), in these cases the number of samples which were tested as well as potential variations in sampling and testing protocols, precluded statistical analysis of this data and a broader conclusion about its prevalence across the industry.

To better understand the prevalence of this phenomenon, it is necessary to analyze physical properties of a much larger number of CIPP installations under conditions where field sampling, test specimen preparation and testing have been controlled using consistent protocols. Recently, research from large projects consisting of hundreds of samples meeting these requirements has been published (Pharand & Rancourt 2015), (Araujo & Yao 2019). Both of these examples from different jurisdictions demonstrate that when comprehensive well managed QA/QC processes are employed in projects with most or all CIPP installations sampled and tested, a relatively predictable proportion of CIPP pipes will exhibit issues with either flexural properties or wall thickness or both, which must then be addressed by the installer and/or contract administrator to ensure that the Owner receives design compliant CIPP. Paradoxically, a large majority of CIPP projects do not include any post installation physical testing of the installed liner.

3.0 CAPABILITY OF CIPP PROJECTS TO DELIVER DESIGN COMPLIANCE

Like any complex construction project many factors need to be considered and controlled to ensure that the final built product meets the Owners' requirements and CIPP rehabilitation is no exception. Unlike traditional "factory manufactured" pipes, the field manufactured nature of CIPP increases the variability of the final installed product. The objectives of sewer rehabilitation using CIPP are defined in the NASTT CIPP Good Practices Guidelines as:

- Arrest internal deterioration of the host pipe
- Stabilize the existing pipe-soil structure by arresting infiltration, the primary driver for most sewer degradation
- Support external groundwater pressure and where required, external soil and surface loads
- Maintain or improve hydraulic capacity of the rehabilitated pipe

To demonstrate that these objectives have been achieved within a CIPP installation, it is necessary to perform specific quality control tests of the installed liner. As part of a comprehensive QA process, this data permits the contract administrator and installer to take a collaborative approach to evaluating liners which are found to be deficient and to implement a evidence-based solutions to address these deficiencies.

Performing post-installation inspections of CIPP installations obviously incurs a cost to a project. Deciding not to perform these inspections may reduce this cost but it also comes with risks. Some of the more obvious risks are that service connections may not have been reopened and fins may be present in the invert leading to blockages, resin may have been washed out of the tube leading to leaks in the liner and in the worst case the physical properties of the liner are insufficient to provide the necessary structural support and life extension to the existing asset. The two post-installations inspections typically employed today to identify these types of deficiencies are visual examination by CCTV and acceptance testing for flexural properties and wall thickness.

In the absence of data demonstrating the prevalence of these types of deficiencies in CIPP installations, it is difficult for an owner to judge the value of requiring these post-installation inspections in their projects. While both CCTV and acceptance testing are inspection practices recommended by national standards such as ASTM F1216 and industry specifications such as the NASSCO CIPP Performance Specification Guideline, there are very few resources which owners can use to evaluate the cost/benefit consequences of implementing – or not, these inspection practices.

3.1 Post-Installation CCTV Inspection

When compared to the objectives of CIPP sewer rehabilitation which were defined earlier, CCTV inspections can directly identify if two of the four objectives (arresting infiltration and maintain or improve hydraulic capacity) have been met at the time of the inspection. Evidence of other features may be visible with CCTV but these features cannot normally be used to confirm that the other structural related objectives have been met.

The authors are aware of only one paper which examines the prevalence of visual defects (ie. defects evident with CCTV inspections) across a defined population of CIPP installations (Shelton 2012). This data was collected from CCTV inspections of 50 miles of mainline liners and 1,200 lateral liners and identified four types of defects evident in these installations, pinhole leakage, seam leakage, sheet delamination and strip delamination. The inspections were carried out at different intervals following installation, immediately after installation (also sometimes referred to a V3 inspection), 60 to 120 days after installation and 2 years after installation (these delayed inspections are sometimes referred to as warranty inspections). The paper does not explicitly state this but it is assumed that every installation was inspected with CCTV.

The study found that evidence of defects varied with the length of time which elapsed between the time of installation and the time of the CCTV inspection. In CCTV inspections performed immediately after installation, zero defects were found but when these inspections were repeated after two years had elapsed since installation, 57 percent of liner segments showed defects. Leakage through the liner into the sewer was the principal defect found during these warranty inspections. These findings by themselves are not indicative of design compliance (for instance and ASTM F1216 Appendix X1 design) but may provide a reason for a follow-up compliance test such as a leakage test or an acceptance test using direct cut samples taken from the installed CIPP.

3.2 Post-Installation Acceptance Testing

Acceptance testing is also a recommended post installation inspection. This involves making a field sample of the same materials used within the individual CIPP installation and curing these materials in a mold (either a restrained cylinder or a flat plate) using conditions representative of each individual installation. The wall thickness of the restrained field sample is measured, test specimens are then prepared from this and these are then tested for flexural modulus and flexural strength (ASTM D790). These test results are then reviewed against the project design requirements to determine if the liner meets the project's structural properties design objectives. When supported by appropriate type testing and a liner design, acceptance testing of an installation can directly demonstrate that internal deterioration of the host pipe will be arrested and that external ground water pressure and soil and surface loads will be supported.

Recently, research from large projects consisting of hundreds of liners where field sampling, test specimen preparation and testing have been controlled using consistent protocols, has been published. The City of Montreal is the 10th largest in North America and has employed a continuous program of sewer and watermain rehabilitation since 2008. Between 2013 and 2015, the city employed three installers to rehabilitate 101.3 km (62.9 miles) of sewers (Pharand & Rancourt 2015). From these sewer installations the city sampled and tested within their own materials testing laboratory 218 individual liners. The samples were either restrained cylindrical samples as described in ASTM F1216 section 8.1.1 or a modified[1] direct cut sample which was removed from the side of ovoid brick lined sewer.

The test results for these liners were compared with both ASTM F1216 Table 1 as well as design minimum requirements for flexural modulus and flexural strength (Figure 1). In addition, the measured wall thicknesses were compared with the design thickness and wall thicknesses which were found to be less than design were reconciled using the flexural test results. When compared with ASTM F1216 Table 1 minimums the flexural strength of 15.1 percent of the liners and the flexural modulus of 6.0 percent of the liners were found to be less than required. When compared with the design requirement, the test results for both the flexural strength and flexural modulus of 22.9 percent of the liners were found to be

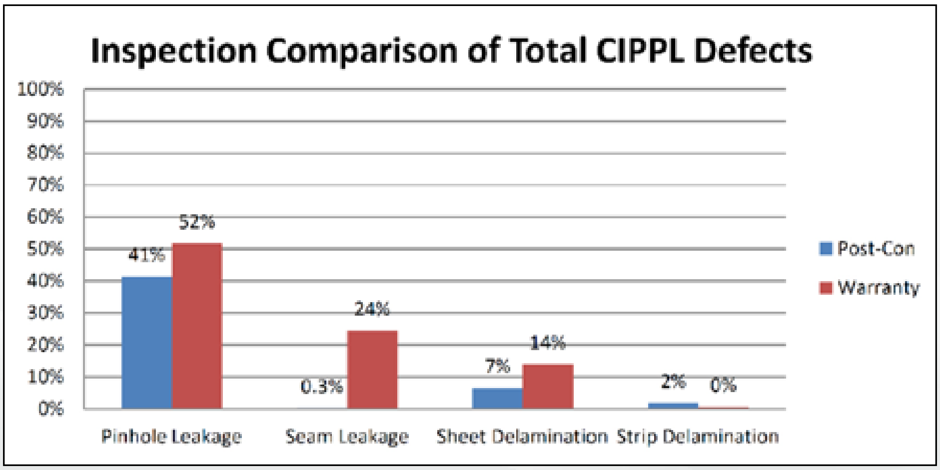

Figure 1. Summary of CIPP defects found with CCTV inspection (Shelton 2012)

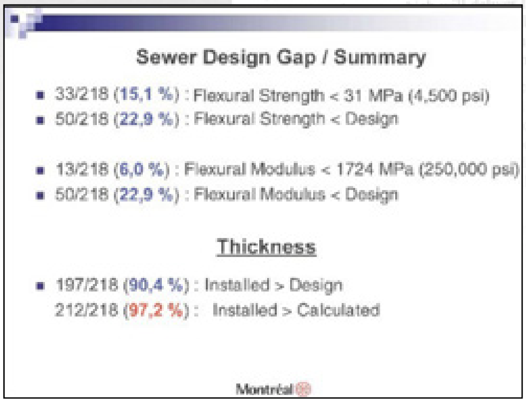

Figure 2. Summary of test results and reconciliation for 218 CIPP liners (translated from French) (Pharand & Rancourt 2015)

less than required. Finally, 9.6 percent of the liners exhibited wall thickness which was less than the design. After reconciliation using the flexural test results where those results exceeded the design requirement, 2.8 percent of the liners were found to be deficient.

Toronto Water is one of North America's largest water, wastewater and stormwater utilities servicing the needs of more than 3.6 million residents. The utility typically rehabilitates on the order of $40 million ($30 million USD) of sewer mains and trunk lines and a comparable amount of watermains each year. As part of this program, between 2017 and 2018 the utility employed three installers to rehabilitate projects totaling 379 sewer segments (Araujo & Yao 2019). From these sewer installations the city sampled each segment and had these samples acceptance tested at a local independent materials testing laboratory. The samples were either restrained cylindrical samples (338) or plate samples (41) as described in ASTM F1216 section 8.1.1 and 8.1.2.

The utility also required the installer to provide the liner design to the laboratory for each segment in order to simplify initial design verification. The laboratory performed this initial verification by replacing the design values which were used in the installers ASTM F1216 X1 design with the values of flexural modulus and flexural strength which were measured by the laboratory. This confirmed whether the measured thickness was deficient or not after verification. The verification process is outlined in the Toronto Water specification TS 4.10.

These design verifications were performed using test data which was derived only from the restrained cylindrical samples. As written, the verification procedure requires that the wall thickness be measured in accordance with ASTM D5813 which requires a complete cylindrical ring sample of the CIPP. Only laboratory test reports for these samples included a conclusion for this initial design verification. Nonetheless, since the restrained samples represented the majority (89 percent) of all of the samples, including this information on these test reports increased the project management efficiency.

The final result of this design verification process for the individual installers is summarized in Table 1. Installer performance varied from no liners being deficient to 10.1 percent being deficient after design verification. Averaging the data for all three of the installers for comparison purposes (only for the purpose of comparison to the previously described Montreal data), 7.6 percent of the 338 liners were found to be deficient after design verification.

Table 1. Percentage of restrained cylindrical samples exhibiting deficient wall thickness after initial design verification

Installer	Design Deficient Wall Thickness (%)
A	0
B	2.4
C	10.1

4.0 WHAT INSPECTIONS DO OWNERS TYPICALLY REQUIRE OF CIPP INSTALLATIONS?

Given the evidence described here of the visual and structural deficiencies which are found in CIPP installations, one would presume that the post-installation inspection practices defined by owners would be designed to capture these defects. To understand if this is the case, in 2022 a review was conducted of the inspection practices defined in the sewer CIPP specifications employed by 33 US municipalities[2]. Together these owners represent a combined population of 126 million. The documents were reviewed to determine if the CIPP installation specification required the installer or the owner's representative to perform the inspections which are described within the inspection studies referenced earlier. The post-installation inspection practices reviewed were:

- CCTV inspection of the completed liner immediately after installation (V3)
- CCTV inspection prior to the end of the warranty period
- Acceptance testing of every installation
- Acceptance testing of a portion of installations

The data showed that all owners required a V3 inspection immediately after or within a short period after the installation was completed. The requirement for a warranty CCTV inspection was much less prevalent with only 7 percent of owners requiring a follow-up inspection prior to the end of the warranty period (Figure 3). The warranty periods for these specifications ranged from 24 to 36 months.

The prevalence of acceptance testing across this group of owners was much less consistent. The majority of Owners, 67 percent, required no acceptance testing on their CIPP projects or their requirement for acceptance testing was sufficiently ambiguous that the installer could expect that no acceptance testing would be required to be performed. Twenty-four percent of Owners required acceptance testing of all liners with the remaining 6 percent requiring acceptance testing frequencies of 20 to 50 percent of installations (Figure 4).

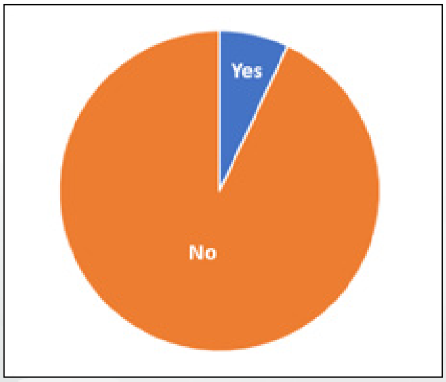

Figure 3. Proportion of owner CIPP specifications which require warranty CCTV inspection

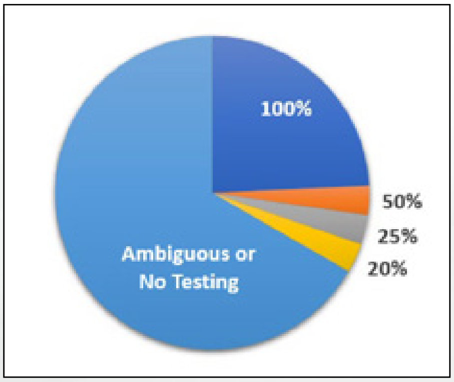

Figure 4. Acceptance testing frequency described within owner CIPP specifications

5.0 DISCUSSION

CIPP rehabilitation technology has been used since 1971. ASTM F1216, the first national consensus standard practice for CIPP was published in 1989, 5 years prior to the Insituform patents on the technology expiring. Since then, the document has been reissued 14 times up to and including the most recent version in 2022. All of the owner specifications reviewed here reference ASTM F1216. While there have been many revisions in other areas of the document over this period, the inspection requirements present today are nearly identical to the original document.

ASTM F1216 defines four post-installation requirements that may be verified on a CIPP installation. A summary of these verifications, whether they are optional or mandatory and whether they have a documented verification method is shown in Table 2.

Some of the post-installation verifications defined in ASTM F1216 are optional while others are mandatory as

Table 2. Post-installation verifications as defined in ASTM F1216

	ASTM F1216 Terminology	Mandatory or Optional?	Defined Method?
Structural Properties	5.2 - "The CIPP system *shall* be *expected* to have as a minimum the initial structural properties given in Table 1." 8.1 – "For each inversion length *designated by the owner*… the preparation of a CIPP sample is required."	Optional	Section 8.
Wall Thickness	8.6 – "The average thickness shall be calculated using all measured values and *shall* meet or exceed minimum design thickness *as agreed upon between purchaser and seller*." 8.6 – "The minimum wall thickness at any point *shall* not be less than 87.5 % of the specified design thickness *as agreed upon between purchase and seller*."	Optional	Section 8.6
Leakage – Pressure Pipe Testing	8.2 – "*If required by the owner*…, gravity pipes shall be tested…" 8.3 – "*If required by the owner*…, pressure pipes shall be subjected to a hydrostatic pressure test."	Optional	Section 8.2; 8.3
Workmanship - Inspection & Acceptance	7.8 – "The finished pipe *shall* be continuous over the entire length of an inversion run and be free of dry spots, lifts, and delaminations." 8.7 – "The installation *shall* be inspected visually if practical, or by closed-circuit television if visual inspection cannot be accomplished." "No infiltration of groundwater *shall* be observed through the CIPP itself. All service entrances shall be accounted for and be unobstructed."	Mandatory	No method defined

indicated by the use of the word shall in the text. One verification, the structural properties requirements, appears to be a hybrid, both simultaneously mandatory ("The CIPP system *shall* be…") as well as optional, ("…*expected to have* as a minimum the initial structural properties …").

This verification together with wall thickness and leakage and pressure testing are optional, expected only to be performed when the owner requires them. Only the visual inspections defined in Section 7.8 Workmanship and Section 8.7 Inspection and Acceptance are mandatory as indicated by the use of the word "*shall*".

Notably, the three optional verifications all include a defined method for the user to follow in performing the verification. On the other hand, the mandatory visual examination does not define how to determine if a liner is

> "…continuous over the entire length of an inversion run and be free of dry spots, lifts, and delaminations."

even though the outcome of this specific verification is the only one in ASTM F1216 subjected to a prescriptive remedy if the inspection does discover them,

> "[if] these conditions are present, remove and replace the CIPP in these areas."

It's not surprising that owner specifications based upon ASTM F1216 have evolved to the point where they are today. Given the broad discretion available to the user and the necessity for the owner to decide whether to perform or not the majority of post-installations inspections, the content of owner specifications has likely come to reflect the individual specification writers experience, or lack thereof, with CIPP unique characteristics, their knowledge of the design objectives and their perception of the risk of not meeting those design objectives.

All of the owner specifications reviewed here as well as ASTM F1216 require a V3 inspection even though the research presented here (Shelton 2012) show zero defects being found during such inspections. Similar conclusions for the ineffectiveness of V3 inspections to confirm design objectives have been documented by other studies (Kampbell, et al 2011), (Bosseler et. Al 2024). Bossler et reported that,

> "Whilst CCTV will confirm the positioning of a liner and will show up geometrical imperfections such as wrinkles that could affect serviceability of the sewer, it does not provide any information on the physical properties of a liner."

Where CCTV appears to have more benefits ie. by confirming the absence of infiltration of groundwater through the liner, almost all of the owner specifications reviewed do not require a warranty CCTV inspection precisely when infiltration is more likely to be evident.

For acceptance testing the evidence appears more encouraging. A significant portion of owner specifications (24 percent) require acceptance testing for every liner. Owners collecting data from these comprehensive programs should expect to see comparable proportions of deficient liners requiring some form of mitigation as is reported in the research reviewed here. However, a large majority of specifications do not require any acceptance testing. This is surprising outcome for owners since when installers are surveyed on their views of acceptance testing, installers recommend acceptance testing to verify the structural properties (Kampbell et al 2011).

Perhaps owners understand that a certain portion of liners will be deficient but they are nonetheless willing to live with this information because by not requiring acceptance testing, they not only save the cost of the testing itself but also all of the management of the data and administration of the mitigation measures when deficient liners are identified. Other owners may become comfortable working with an installer and feel that they are obtaining acceptable value without the additional expense of acceptance testing (Kampbell et al. 2011).

The research presented here for comprehensive acceptance testing programs found between 2.8 percent and 10.1 percent of liners were deficient after acceptance testing and reconciliation of most or all liners. 57 percent of liners showed some visible defect during a warranty CCTV inspection. Having this information in hand, owners would normally hold payment for these liners until some form of mitigation was agreed to with the installer, or a more detailed engineering analysis showed that the liner was acceptable, or a liner removal and replacement or partial payment for the liner was negotiated. These mitigation measures are usually additional costs to the installers or savings to the owner where partial payment is considered. In either case the deficient liner is either remedied with an acceptable line or the owner pays less for a liner which is likely to provide less value over the life of the liner.

6.0 BUT WHAT'S MISSING FROM THIS DISCUSSION?

Given the demonstrated rates and types of post-installation deficiencies, can an owner actually reduce the cost of a CIPP project by not performing post-installation inspections and still obtain an asset of known quality and comparable value? Can the reported deficiency rates be projected to other CIPP projects? Unfortunately, the authors are not aware of any research which has addressed this question.

To obtain statistically significant conclusions. one would need to perform warranty-type CCTV inspections and acceptance testing of a large enough number of already installed liners. For this study to be based on the correct context, the liners would have to have been installed without the owner originally requiring acceptance testing or warranty CCTV inspections. While a study involving CCTV inspections of already installed liners would not pose a significant hurdle, there are likely many candidate projects where such an examination could be arranged, acceptance testing on such a scale would. Either liners would need to be exhumed with the host pipe or the cavity left behind from taking a direct cut sample would need to repaired. Both options would be expensive.

The limited retrospective studies where liners have been acceptance tested sometime after installation provide hints that deficiency rates may be higher than these reported here in the Montreal and Toronto examples (Allouche et al 2014) reported in their retrospective study

> "…only one of the five [CIPP] samples retrieved had a thickness higher than the value specified at the time of its installation"

however, the limited number of samples analyzed, make it difficult to draw conclusions from these data.

The evidence presented for Montreal and Toronto is for projects where the installers understood that deficient liners were highly likely to be identified during post-installation inspections. All bidders would have this equal understanding prior to bidding and would bid the project accordingly and then execute the project on the same basis, understanding that all installers would face the same risks. This means that the deficiency rates reported in these three studies probably represent the best-case post-installation deficiency scenario which can be expected from a well-managed CIPP project. In the absence of post-installation inspection data from CIPP projects where owners have allowed installers to self-monitor the quality of their installations, is there is another way quantify the potential extent of deficient liners where owners chose not to look for them? Perhaps an analogy from a different industry would help.

6.1 Shrinkage And The New Supermarket Self-Checkout

The first North American supermarket, the King Kullen opened in New York City in 1930 (G&M 2023). The new supermarket business model brought a quantum leap in convenience and product selection to customers. Where previously shoppers had to ask a clerk for a product, wait for them to retrieve it from a stockroom and then discover what it looked like and how much it cost, now they could wander the aisles of a well-lit spacious store, examine the selection of products available and confirm price and quality before selecting their purchase. Since all products were easily available to every customer in the store, retailers now had to have a system to ensure that product didn't leave the store without being paid for and so the ubiquitous checkout was invented, with a cheery cashier, a cash register and the checkout line.

However, unlike the old retail model where most products were kept in a stockroom only accessible by a clerk, the new model, where every product was available to the customer came with a new problem for the retailer, shrinkage.

Shrinkage is defined as "…items that left a store or warehouse without being paid for." (NYT 6/2/2023) and has always been a problem in the retail business, but shoplifting which is one form of shrinkage, became a more significant problem as customers gained better access to the products on the shelves. The National Retail Foundation, the world's largest retail trade association reported that the average rate of retail shrinkage in FY2022 was 1.6 percent of retail sales (NRF 2023). This figure represents a loss of $112.1 billion to the industry. With shrinkage being such a significant and recurring issue, the retail sector has undertaken studies to measure the sources of shrinkage and the impact that specific loss prevention measures have on mitigating it.

Having a cashier handle every product in order to checkout a customer incurs a sizeable labor cost to the retailer. Not having a cashier checkout a customer incurs a risk that the customer will not pay for the merchandise. Lately retailers have been trying to reduce these labor costs by relying more and more on technology that allows customers themselves to checkout and pay for their merchandise. Mobile or fixed self-check outs (SCOs) are now present in most retail stores today and naturally have reduced checkout labor costs for retailers. However, along with these labor cost reductions, the retail industry has also begun to document much higher rates of shrinkage. This higher level of shrinkage appears to be associated with the new SCO checkout model.

In order for the retail industry to retain the labor cost savings that SCO is bringing to their stores while minimizing the apparent higher levels of shrinkage associated with it, researchers have recently begun to study the issue. The objective of this research is to confirm if SCO related shrinkage is occurring and if it is, to determine level of shrinkage, its cost and the effectiveness of different mitigating measures. This requires the researcher to study stores which employ either SCO or the traditional cashier model within the same retail chain. Examining a large retail chain with many locations provides the researcher with higher resolution data and ensures that the mix of merchandise checked out by the two types of checkout are the same.

Depending on the type of retail environment the SCO technology used and the audit techniques employed by the researchers SCO was found to have higher shrinkage rates than cashier checkout. One university researcher found shrinkage for SCO ranging anywhere from 33 to 147 percent greater than without SCO (Beck, 2018).

Given these early findings, SCO related shrinkage has become enough of a problem that some retailers are removing SCO technology and reverting back to cashiers (Business Insider, 2023). While some of this increased shrinkage is due to outright theft, ie. customers not scanning a product intentionally or entering a product code for a less expensive product, some of it is accidental. A study found that 21 percent of SCO users accidentally took an item without scanning it. Most telling about this segment of “honest” users was that 61 percent of them kept the product anyway and only 29 percent returned it (Lending Tree, 2023).

6.2 Retail Self-Checkout – The Relevance To CIPP Quality Assurance

Almost three quarters of owner CIPP specifications examined require little to no acceptance testing of their CIPP installations. Presumably these owners also want these installations to provide the structural and hydraulic objectives which their specifications all require, however these benefits are only achievable if the installed liners meet their design objectives. In the authors experience, owners frequently justify this disinterest in acceptance testing of CIPP projects because, whether are not they have performed sporadic random testing, they have not found any "failures". "Absence of Evidence is not Evidence of Absence" is a quote by Carl Sagan, a famous American astronomer. Feres and Feres spelled out Sagan's quote:

> "Its importance relies on the highlight of the logical fallacy where a hypothesis is assumed to be true or false before being scientifically and satisfactorily investigated."

The research on QA/QC of CIPP projects shows that best rates of deficient liners after acceptance testing and reconciliation achievable for comprehensive programs can be as low as 2.8 to 10.1 percent of installed liners. The limited information available on less comprehensive sampling programs suggests that the proportion of deficient liners may be higher than these figures. Without a significant source of funding and a host owner willing to exhume or sample a large number of completed liners, we are unlikely to determine the actual number of deficient liners which result from a program where the installers understood that acceptance testing would not be performed on their work.

In this absence of evidence on the rate of deficiencies in CIPP liner projects where little to no acceptance testing has been performed, the authors submit that this type of quality assurance model is analogous to the SCO retail checkout model where the retailer trusts the customer to check out their merchandise. As the retail industry research demonstrates, the SCO model, while saving direct labor costs also results in more merchandise leaving the store unpaid when compared to the human cashier model of retail checkout.

If one applies the rates of additional shrinkage for SCO compared to human checkout measured in the research to the rates of deficiencies of comprehensive CIPP QA/QC programs its possible to infer that in the best-case scenario deficiencies could as low as 3.7 percent to as high as 14.7 percent in programs without comprehensive acceptance testing. The worst case scenario could be as recoded by Allouche where 80 percent of liners examined exhibited wall thickness less than the design. The likely reality is probably somewhere between these two figures.

7.0 CONCLUSIONS

Cured-in-place-pipe (CIPP) has demonstrated that it can be an effective rehabilitation technology when implemented within an appropriately managed project. The research shows that even with these well managed projects deficiencies will occur which need to be mitigated in order to provide the owner with an asset which meets their design objectives. Very little research exists into the quality of liners which were installed under less-comprehensive inspection regimes. What little research does exist appears to show that deficiency rates may be significantly higher.

While the self-checkout statistics may not a perfect analogy for deficiency rates in CIPP projects where owners do not look for deficiencies, it does provide statistically significant data which illustrates the outcome when a retailer relies only on trust to ensure that customers pay for the products which they leave their store with.

Owners who don't implement post-installation protocols designed to identify the types of deficiencies which are known to occur in CIPP installations, but instead trust installers to self- verify the quality of their installations, should expect that these liners likely contain much higher rates of deficiencies. President Ronald Reagan quoted the Russian proverb "trust, but verify" when he met with the Soviet Premier Gorbachev to indicate that trust isn't always enough to guarantee a favorable outcome. Owners who don't verify the quality of their CIPP installations are effectively like retailers whose stores have no checkout lanes and they trust that all customers will pay for their products before leaving the store. Our review of owner CIPP installation specifications indicates that the majority of owners trust installers to self- checkout the assets that owners are paying for.

8.0 FOOTNOTES

[1] The modification defined in DTNI-2B-100 requires the installer to fasten a 3 mm (1/8") thick steel plate to the inside of the sewer in the location where the direct cut sample is to be later removed. The liner is cured over top of the steel plate. After curing is completed. the direct cut sample and steel plate are removed. The end result is a flat plate of CIPP which closely resembles the actual pressure and temperature installation conditions within the sewer. The resultant cavity is repaired using a city approved process.

[2] The US cities included in the review were Atlanta, Austin, Baltimore, Boston, Charlotte, Chicago, Cincinnati, Denver, Fresno, Hartford, Kansas City, Las Vegas, Los Angeles, Louisville, Milwaukee, Minneapolis, New Orleans, New York, Oklahoma City, Orlando, Philadelphia, Phoenix, Pittsburgh, Portland, Richmond, Salt Lake City, San Antonio, San Diego, San Jose, Seattle, Tampa, Tulsa and Washington.

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NASTT Events Calendar

Since its inception in 1991, the NASTT No-Dig Show has been the premier North American conference and trade show for the trenchless technology industry. Thousands of professionals from around the globe attend to learn new methods and systems that will save money and improve infrastructure. This conference provides attendees an opportunity to learn trenchless methods, network with peers and gain knowledge from vendors during exhibit hall hours.

The NASTT No-Dig Show is the ideal event for municipalities, contractors and engineers.

Upcoming Conferences, Courses & Events

February 20
Southeast Topgolf Social
Lake Mary, Florida, USA

February 26 – 27
HDD Good Practices Course - *All New*
Virtual

February 27
Northwest Technical Luncheon
Edmonton, Alberta, Canada

March 30 – April 3, 2025
NASTT 2025 No-Dig Show
Denver, Colorado, USA

March 30
Introduction to Trenchless Technology – New Installations
Denver, Colorado, USA

March 30
Introduction to Trenchless Technology – Rehabilitation
Denver, Colorado, USA

April 2
Municipal Sewer Grouting Good Practices Course
Denver, Colorado, USA

April 2
Sewer Laterals Good Practices Course
Denver, Colorado, USA

April 2 - 3
HDD Good Practices Course
Denver, Colorado, USA

April 2 - 3
New Installation Methods Good Practices Course
Denver, Colorado, USA

April 2 - 3
CIPP Good Practices Course
Denver, Colorado, USA

April 2 - 3
Pipe Bursting Good Practices Course
Denver, Colorado, USA

April 2 - 3
Direct Steerable Pipe Thrusting Good Practices Course
Denver, Colorado, USA

June 2 - 3
Northwest Chapter Trenchless Technology Symposium
Calgary, Alberta, Canada

October 27 - 30
NASTT 2025 No-Dig North & ISTT International No-Dig
Vancouver, British Columbia, Canada

March 29 - April 2, 2026
NASTT 2026 No-Dig Show
Palm Springs, California, USA

November 2 - 4, 2026
NASTT 2026 No-Dig North
Calgary, Alberta, Canada

For more information and the latest course offerings, visit nastt.org/training/events.

March 30 - April 3, 2025
Colorado Convention Center
Denver, Colorado

March 29 - April 2, 2026
Palm Springs Convention Center
Palm Springs, California

SPONSORSHIPS:

For more information and the latest course offerings, visit nastt.org/training/events.

There are a variety of sponsorship opportunities for every price range:

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