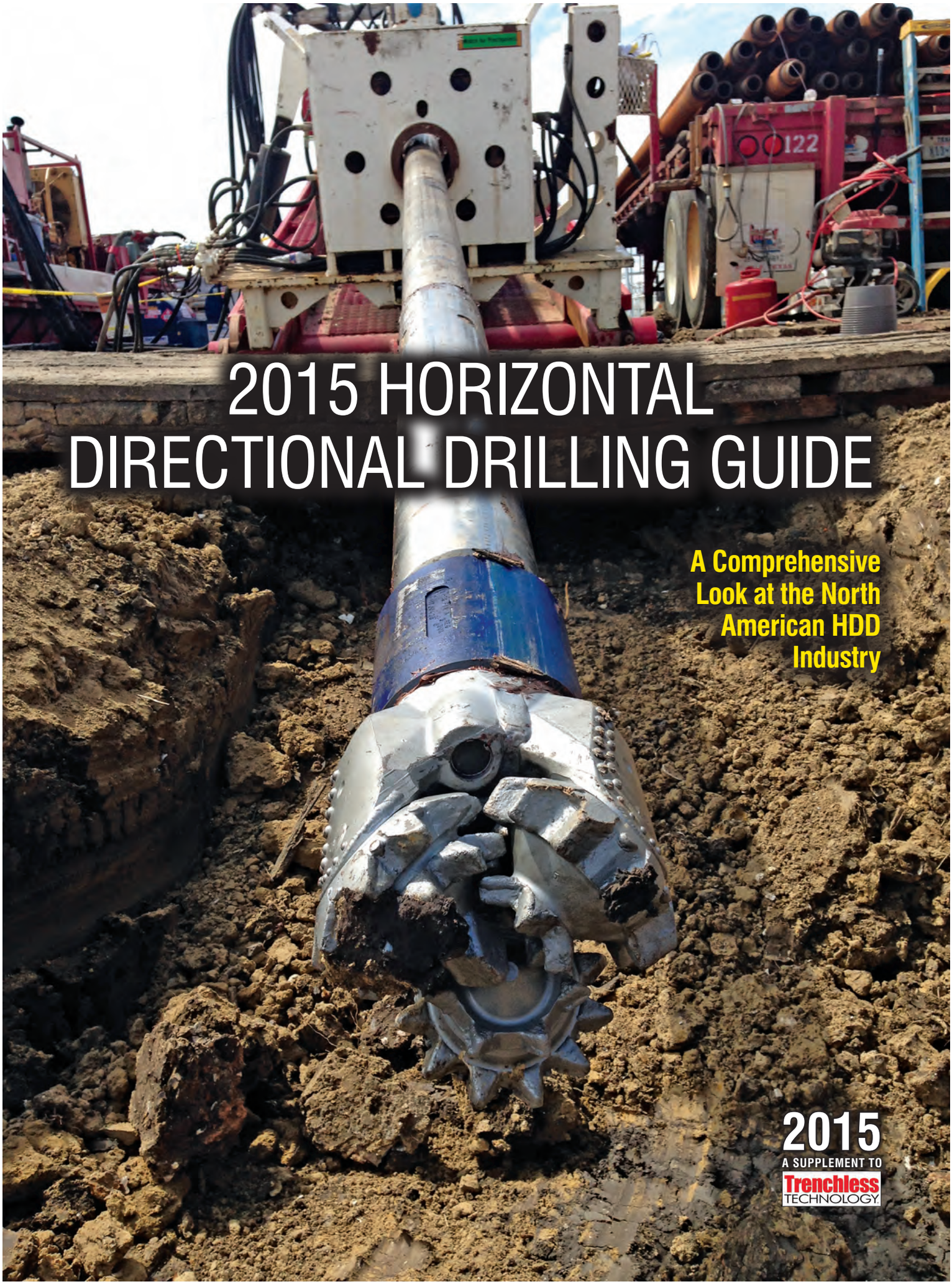

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2015

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EDITOR'S MESSAGE

HDD Connects with Wireless Market

The *2015 Horizontal Directional Drilling Guide* in your hands marks our fifth annual publication devoted to the horizontal directional drilling (HDD) industry. Each year we have produced this book, it has grown in size, matching the interest by both our readers and advertisers.

Things are going well for the HDD industry these days. Though some of the oil and gas work has slowed, the important thing is that there is still work to be done in these sectors. Water and sewer work continues, even though funding, as always, is an issue.

The healthiest HDD market today lies with the fiber and telecommunications field. These deployments has really taken off over the last few years and doesn't show any signs of tapering off. Why should it? Digital is everything today and the broadband and cable providers are pushing to expand their networks to meet the increasing demand. 3G is so yesterday — today and tomorrow are about 4G and 5G networks (for now!).

The HDD industry has seen this before but with a much different impact. The fiber boom of the late 1990s was more of a short-term boost for HDD that had devastating results when the work was completed — the HDD industry was at its lowest point and remained there for several years. As FMI Capital Advisors president and senior managing director Chris Daum told me, "The fiber deployments of the late 1990s and early 2000s were highly speculative," reflecting the early years of the Internet and dot coms.

The fiber deployments today reflect a much different projection and market position as the digital age is no longer a luxury for society but a necessity — for businesses and your personal day-to-day activities. From watching television, to paying your bills, listening to music, to running your jobsite and making construction purchases — everything is done via a laptop, cell phone or computer. And that's not going to change.

As a result, equipment purchases for compact to midsize rigs are strong right now, as well as ancillary equipment for these jobs, such as drill pipe. As one manufacturer told me, contractors today are buying drill pipe but it's just at a smaller diameter than in past years. ICUEE 2015 is in a few short months (Sept. 29-Oct. 1) and I have no doubt that the HDD industry will be rolling out some cool rigs (Ditch Witch and Vermeer already have) and other technology to meet the contractors' needs.

For more on the HDD market, check out my article on pg. 8.

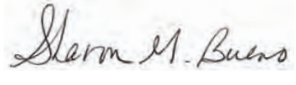
If you're looking for a new rig and other parts for your toolbox, we can help you out a bit. As with each *HDD Guide*, we have included our Product Showcase and Drilling Rig Specs sections. These sections give you a glimpse as to what is available to you to make the most out of your project opportunities. The response to our call for participation in these sections has grown exponentially each year we have put this book together and we love it! Keep it up guys!

I also wanted to mention that in 2015 Benjamin Media and Arizona State University's Del E. Webb School of Construction teamed to produce an outstanding HDD educational event — the HDD Academy. In 2016, we are once again working together to bring the HDD industry this terrific program. The 2016 HDD Academy takes place Feb. 11-12, at the Tempe Mission Palms Hotel in Tempe, Ariz. Last year's inaugural event was sold out for attendees and we believe the 2016 event will do the same. For more information, check out the story on pg. 30 or visit the website at *hddacademy.com* for the latest information regarding sponsors, agenda and networking opportunities.

We have some really cool project stories in this year's book — we hope you enjoy them and the entire *2015 Horizontal Directional Drilling Guide*.

Until next year!

Sharon M. Bueno



Managing Editor

Trenchless TECHNOLOGY

PUBLISHER
Bernard P. Krzys
bkrzys@benjaminmedia.com

EDITORIAL
Editor: James W. Rush
jrush@benjaminmedia.com

Managing Editor: Sharon M. Bueno
sbueno@benjaminmedia.com

Assistant Editor: Mike Kezdi
mkezdi@benjaminmedia.com

Contributing Staff Editors:
Andrew Farr • Brad Kramer
Keith Gribbins • Pam Kleineke

SALES+MARKETING
Marketing Director: Kelly Dadich
kdadich@benjaminmedia.com

Brand Sales Manager: Dan Sisko
dsisko@benjaminmedia.com

Conferences Sales Representative: Brittany Maurer
bmaurer@benjaminmedia.com

PRODUCTION+FULFILLMENT
Production Manager: Chris Slogar
cslogar@benjaminmedia.com

Lead App Designer/Graphic Designer
Deb McManus

Web/Interactive Manager: Mark Gorman
mgorman@benjaminmedia.com

Circulation & Fulfillment Specialist: Lillian Lopeman
llopeman@benjaminmedia.com

REPRINTS
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BENJAMIN MEDIA

Chief Executive Officer: Bernard P. Krzys
bkrzys@benjaminmedia.com

President: Robert Krzys
robk@benjaminmedia.com

Controller: Marianne Saykes
msaykes@benjaminmedia.com

10050 Brecksville Rd.
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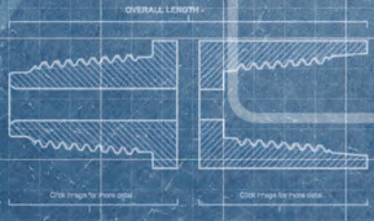

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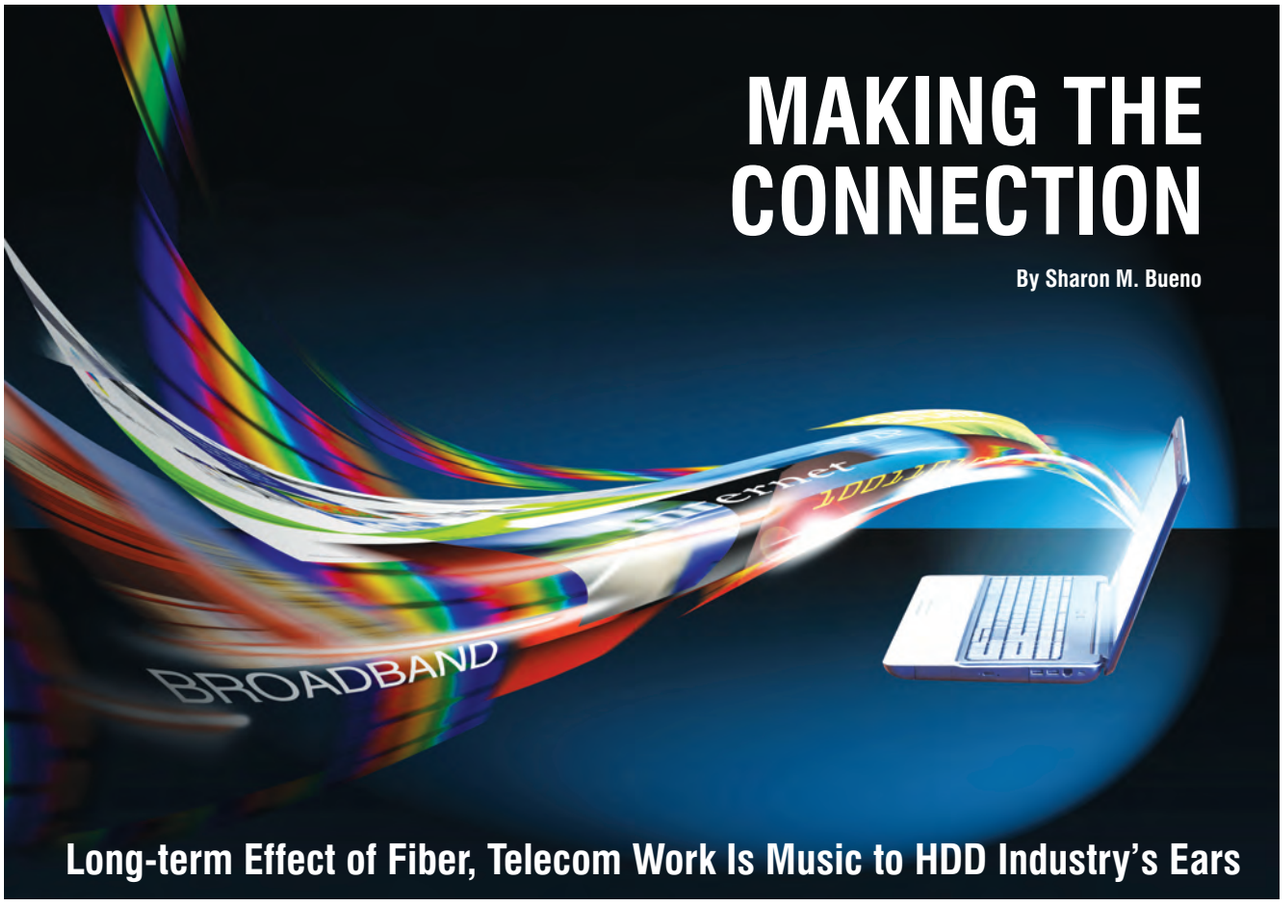

MAKING THE CONNECTION

By Sharon M. Bueno

Long-term Effect of Fiber, Telecom Work Is Music to HDD Industry's Ears

Horizontal directional drilling (HDD) definitely has a positive vibe to it these days, giving the industry the proverbial bounce in its step and a good jolt of long-term optimism. From water and sewer work to oil and gas to the fiber optic/telecom market, HDD seems to be enjoying a buoyancy it hasn't felt in a long while.

People want to talk about HDD and learn more about it. There's a new generation of drillers pulling back the product pipe and they are thirsty for knowledge.

"It is a good year to be a directional driller," says Vermeer senior global product manager for underground Jon Kuyers. "It's not the manufacturers saying it. The manufacturers are seeing the results of a good market. Our core trenchless products are very strong. All the market dynamics are very favorable for HDD, whether it's gas, telecom, water, electric or sewer."

"I have referred to this as we may be entering the 'Golden Age of Underground,' which has to do with the fact that through aged infrastructure or these demand-driven infrastructure spending programs around oil, gas, communications or the need to remediate gas distribution lines, aged plants for water, sewer and water supply infrastructure — they are all underground technologies," says Chris Daum, president and senior managing director of FMI Capital Advisors. Daum has been with FMI for 16 years, focusing on utility infrastructure.

"All of that involves underground construction," Daum says. "All of those infrastructures have to be expanded, upgraded, repaired and maintained and there's healthy growth across all of those. HDD is an acceptable and economically cost-effective delivery method that is much more prevalent today [than in past years], which bodes well for HDD services."

THE DIGITAL AGE

One of the healthiest areas that HDD is enjoying a sweet uptick is in fiber optics and telecommunications. Digital is everything today and broadband and cable providers are pushing to expand their networks all over the country to meet this incredible demand. Where 4G and 5G service was unheard of just a few years ago, it's the next "thing" today. FMI estimates that communications capital expenditures will increase to approximately $70 billion this year, with mobile network bandwidth expanding 500 percent over the next four to five years.

The ramping up of fiber-optic and telecommunications line installation has been a boon for the HDD market. Unlike the previous big fiber push of the late 1990s to early 2000s, this substantive increase will have a long-term impact on the market as the demand for more bandwidth and wireless communications continues to be a part of our daily lives. From laptops to tablets to videos to cell phones to music — the list goes on and on for consumers whose thirst for fast, up-to-the-minute information and entertainment only continues to grow.

"The increase in capital spending for communications and broadband is fa-

vorable for the HDD market because it portends more new construction, more fiber deployments because of Google, AT&T and CenturyLink," Says Daum. "Their planned build-outs and private fiber network deployments — all of that will portend to more construction and will drive HDD where these deployments are taking place, into the neighborhoods into the urban infrastructure that is done predominantly underground.

All of this bodes well for HDD as the trenchless delivery method has become a popular option for fiber and telecom installation. The HDD market has seen this before. In the late 1990s, when the Internet was really starting to take off, HDD experienced a huge influx of work as the networks were being constructed. The end of that work coincided with the HDD market bottoming out, taking years to recover.

However, the tremendous upswing in communications work this time around is different, as the long-term demand is there — something that energizes those who sell the compact to midsize HDD drills. "It has really contributed to the case for investing in the small to midsize machine market," says Seth Matthesen, senior HDD product manager at Ditch Witch. "We have seen an uptick [in purchasing] through the last half of 2014 and this year for compact to midsize directional drills like the Ditch Witch JT9 and JT20 … This definitely feels like a more healthy build than what we saw in the late 1990s. There is a steady, healthy demand."

Daum agrees about the difference of today's fiber/telecom market to years past. "The fiber deployments of the late 1990s and early 2000s were highly speculative, meaning they were wholesale, long-haul fiber buildouts because of the Internet boom and dot com bump. In many respects, a lot of that dark fiber and urban interconnects ended up being empty conduit," Daum explains. "Back then, HDD was somewhat in its infancy as an acceptable technology that was unproven and had not been adopted as widely. Vermeer and Ditch Witch pioneered a lot of that growth.

"Flash forward 15 years later and we are living in a bandwidth-rich, interconnected world with a more mature Internet with completely mature e-commerce with demand for data being exponentially greater that it was before. It's a totally different environment than before…The really big difference is that we weren't even talking about video broadband. We weren't talking about mobile data and we certainly weren't talking about 5G. That's all taken place in the last five to seven years.

"What's driven the market the last five years and continues to drive it is the wireless mobility. That's not going away."

Kuyers concurs with Daum and notes how much of everyone's daily lives revolve around digital devices at work and in their personal lives. The proliferation of bandwidth and the demand for fast data has and will continue to have a huge impact on the HDD market, he says. "What is different this go around is that the demand is there for the product and the service," Kuyers says. "People are spending the $100-plus to get the service to their homes. Fifteen years ago, they might not have. Society has changed. People now watch TV on their computers or mobile device. Fifteen years ago, they didn't do that. Everyone has a smart phone today or a tablet. It's how you get your information and how you communicate. All of this used to be a luxury and today it's a necessity," he says.

With all of this demand, HDD is reaping the rewards. Contractors are spending their dollars on new HDD rigs to handle the work, buying both compact and midsize rigs. The speed and power of these machines are perfect for this market, which sees fiber being shot out in 600- and 700-ft lengths, experts say.

"It has really helped the smaller rig market focus on technologies that improve efficiency," Matthesen says. "Contractors working on the jobsite definitely expect increased output from compact and midsize machines. [The fiber/telecom market] has given us the ability to re-invest in those product lines. New products are being developed to meet these growing customer needs. Contractors want a smaller package with more power that is easier to maneuver."

OIL AND GAS

With the fiber and telecom market gaining more momentum and strength,

With the widespread construction of new and expanded communications networks, HDD is working in neighborhoods, which means tighter spaces. Equipment for a smaller footprint is a necessity for today's drillers.

it has offset the tepidness HDD manufacturers say they are experiencing in the oil and gas market. HDD saw a tremendous surge in work the last several years with the emergence the Marcellus and Utica shales plays in New York, Ohio, Pennsylvania and West Virginia, as well as the Bakken shale play in Montana and North Dakota. The work involved new installations to meet the needs of shale gas production to repairing or replacing old lines.

Though the work seems to be there, the oil and gas market is getting mixed reviews from the manufacturers on the impact it's having on HDD drillers.

American Augers director of product management Richard Levings has been involved in the HDD industry for more than 20 years, experiencing the highest highs and the lowest lows that have come and gone during that time. He believes that the lower oil and gas prices the market is seeing has caused some drillers to take a pause in their spending for the time being. "It has caused reserve in the minds of contractors because they have plenty of work today but they're not sure about tomorrow," he says. "They are doing the work with the equipment they already have."

Kuyers acknowledges the oil and gas slowdown from the HDD side but notes that there is still a lot of work out there. "There are still pipelines that still need to be built and will be built and are still being built," he sums up. "That work has not completely stopped. A lot of the markets are underserved, especially as some of the power plants come online that demand for gas will increase. They're going to have to increase the supply to those plants and to existing infrastructure to accommodate for that larger demand."

Daum is more positive in his assessment of the oil and gas market and what it means for HDD. "It's not slowing down at all. That's a big misunderstanding in the market," he says. "You'll have 25 percent more pipe installed in 2015 vs 2014 and [FMI] projects upward to 100 percent increase in pipeline deployments in 2016.

"Drilling activity in certain nonconventional shale plays has slowed because of the price of oil but the midstream infrastructure from gathering pipelines to mainline transmission pipelines to take the product that has been produced away from its source and send it downstream is 18 to 24 months behind the drilling that has already taken place. A lot of that activity is just entering into the construction phase in 2015 and 2016," Daum explains.

Daum describes the construction activity for the gas market as fairly robust and has a favorable outlook because infrastructure in some areas that will be producing gas hasn't been built.

One of the healthiest areas that HDD is enjoying a sweet uptick is in fiber optics and telecommunications. Broadband and cable providers are pushing to expand their networks all over the country to meet the incredible demand. FMI estimates that communications capital expenditures will increase to approximately $70 billion this year, with mobile network bandwidth expanding 500 percent over the next four to five years.

TOPICAL: DRILLING FLUID MISCONCEPTION

To those involved in the HDD industry from its inception know the topic of drilling fluid disposal and regulations have never really been settled. Outside of the HDD industry, there has always been a misconception about the use of drilling fluids: Are they safe? Are they harmful to the environment? How are they disposed? And on and on it goes.

Today, HDD leaders are fighting the same battle as the use of drilling fluids has come under fire, as opponents are confusing it with as the same material used in the hydraulic fracking operations of the oil and gas industry. "Today we have regulations of all kinds as it pertains to drilling fluid handling, disposal, cost, makeup water availability, disposal facilities, etc.," Levings says. "There are a lot of people who are misled to believe that fluid used for HDD is the same as that used in [hydraulic fracturing] in the oil and gas industry and it's not the same thing. HDD drilling fluid is basically soil mixed with water with no chemicals and wouldn't be harmful in anyway."

Disposal costs is a huge issue for contractors, as the costs to transport and get rid of the used mud continue to increase. The use of mud cleaners and recyclers has become commonplace by contractors for projects of all sizes, not just the larger work. Contractors are now using the systems with the compact and midsize units.

"Before it was easy to get rid of your mud. Contractors would just dump it in someone's field," Kuyers says. "Today, people don't want you to do that. We are working in urban areas and there is no space to do it and you have to find a local facility to dump it and it's costing them an arm and leg to do it.

"Every one of these contractors is using a vacuum system and they are sucking up the mud and it costs them money to dump it. This is not just occurring on large back reams. It's an industrywide problem," he adds.

Levings wants the HDD industry to work together to educate the general public, engineers, municipalities, as well as the politicians on what HDD drilling fluid actually is. "We have an industry that needs to work together to help people understand the truth about HDD drilling fluid, so they understand that HDD is a friend of the environment in every way," he says.

Sharon M. Bueno is managing editor of *Trenchless Technology*.

FROM TIP TO TAIL

2015 Horizontal Directional Drill Specs

By Sharon M. Bueno

When shopping for a drill rig, there are many, many options out there. Big or small, the HDD industry has a rig for you. Custom-made or one off the assembly line, not a problem. We want to help you start your buying process by introducing you to what is available. Many contractors have brand favorites but we wanted to give you a well-rounded view of the rigs on the market.

As with every *Horizontal Directional Drilling Guide*, we have include our annual HDD rig catalog. We reached out to the HDD rig manufacturers to share with our readers their product fleet that includes compact, midsize and maxi rigs. The information provided in this section comes directly from the manufacturers to give you just a glimpse of what their rigs are capable of. For more specific data, you will need to directly touch base with the manufacturer.

All the information comes directly from the rig manufacturers. No direct comparisons between equipment or manufacturers are implied. We also asked that the manufacturers offer some tips on purchasing and maintenance.

Sharon M. Bueno is managing editor of *Trenchless Technology*.

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HISTORY

The American Augers line of underground construction equipment consists of: auger boring machines, maxi rig and mid-size directional drills, mud pump and cleaning systems and tooling and accessories. The products are manufactured at the company's 241,000-sq ft facility in West Salem, Ohio. Since the founding of American Augers in 1970, there has never been a change in the company's core value: having products developed by a can-do work force that focuses on mechanical, technological and customer-based design improvements. American Augers was the first HDD manufacturer to use a rack-and-pinion carriage design, which is now the industry standard.

PRODUCTS LINEUP

DD-110 / DD-110S
DD-155T
DD-220T
DD-440T
DD-660RS
DD-1100RS

PRODUCTS SUMMARY

American Augers produces the highest quality mid-size and maxi horizontal directional drills in the industry. The smallest has a push/pull of 110,000 lbs and is a great size for those contractors that are now progressing out of the utility installation and into gas pipeline work. The DD-110 can easily be used for both those applications. Off-board cabins on the mid-size DD-155T and DD-220T increases the visibility for the driller, reduces fatigue due to vibration and allows room for the steering operator. Off-board mud pumps ensure the rig's engine power goes straight downhole instead of to the pump. The best-selling maxi-rig in the industry is the DD-440T. Durable, mobile and most of all, powerful enough for the tough jobs, the DD-440T is the go-to drill rig for contractors around the world because of its versatility and strength. Rapid Set-Up horizontal directional drills are unique to American Augers. The DD-660RS and DD-1100RS allow the driller to pull the rig into position, then rapidly rises to the desired drilling angle. Both are micro-processor controlled and have incredible torque.

Co/ Model	Thrust/ Pullback (lbs)	Spindle Speed (rpm)	Torque (ft-lb)	Pilot Bore OD	Maximum Backream (in.)	Maximum Bore (ft)	Drill Pipe (ft)	Engine HP	Maximum Fluid Pressure (psi)	Flow Rate (gpm)
DD-110	110,000	150	14,000	6	varies	varies	20	260	1,100	200
DD-110S	110,000	150	14,000	6	varies	varies	15	260	1,100	200
DD-155T	155,000	100	30,000	9	varies	varies	20	275	1,500	450
DD-220T	220,000	95	30,000	9	varies	varies	34	365	1,500	650
DD-440T	440,000	80	60,000	9	varies	varies	34	600	1,500	1000
DD-660RS	660,000	90	80,000	13	varies	varies	34	600	1,500	1000
DD-1100RS	1,100,000	75	100,000	13	varies	varies	34	765	1,500	1000

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COMPANY HISTORY

Barbco has been manufacturing directional drills since the mid-1990s. Since then, we have become known as a manufacturer that "really puts the horsepower behind the specifications." Our directional drills will exceed your expectations on how a drill should perform. We start with quality components that have stronger duty cycles and couple them to a higher flywheel horsepower thus creating unmatched performance that the operator can actually feel when on a tough pull. Barbco's machines are used throughout the world on a daily basis with a proven track record of long durability in the field for performance, reliability, better quality construction and a simple design for easy maintenance and operation. When service is required, Barbco once again meets or exceeds our customer's expectations. We have a vast knowledge in field experience both in private, military and government projects and can be of assistance on any project that the equipment is used.

PRODUCT LINEUP:

BD40HP, BD60HP, BD80HP, BD100HP, BD120HP, BD160HP, BD200HP, BD250HP and BD380.

PRODUCT SUMMARY

Barbco custom builds HDDs to suit the needs of its clients. This process has provided Barbco with a vast knowledge of how todays HDD's need to perform. In addition to performance related issues, the design process involves several other topics of discussion. The main topics are: Safety Features, Skeletal Integrity, User-Friendly Controls, Strategic Sensor Development and Placement, Trailering-Transporting, System Diagnostic Reporting , Sensor Overriding and Manual Operating Controls. Combined these topics of discussion are used to design the Rig and ultimately determine the scope of work for the project. Barbco has also created a standard line of HDDs. This product line is designed and built using the systems that Barbco has built into its custom rigs. These rigs are built today to accommodate a smaller job site footprint and as a result create maxi size drills that utilize 20-ft drill stems. The controls are equipped with automated drilling modes and a unique customizable drillers interface. Other features include cabs with room for surveyors and the use of programmable controllers that provide a flexible, expandable and cost-effective total machine management system.

ADVICE TO BUYERS

When purchasing your next Rig, take the time to choose your equipment wisely. Be sure to review the specifications before the price and pay close attention to the components your Manufacturer has chosen to use. It could be that your machine was engineered for high parts sales. BEWARE OF THIS AND BUY SMART!

MAINTENANCE TIP

Stay on top of replacing air, fuel and oil filters. Using service indicator gauges is an easy way to know when it's time to change a filter. Grease all moving parts and change air and oil filters regularly.

Co/ Model	Thrust/ Pullback (lbs)	Spindle Speed (rpm)	Torque (ft-lb)	Pilot Bore OD	Maximum Backream (in.)	Maximum Bore (ft)	Drill Pipe (ft)	Engine HP	Maximum Fluid Pressure (psi)	Flow Rate (gpm)	Fluid Tank (gal)
Barbco BD40HP	40,000	250	6,600	--	--	--	10	201	1,000	70	--
Barbco BD60HP	60,000	220	12,500	--	--	--	15	225	1,000	130	--
Barbco BD80HP	80,000	170	15,000	--	--	--	20	250	1,000	200	--
Barbco BD100HP	100,000	170	15,000	--	--	--	20	300	1,000	275	--
Barbco BD120HP	120,000	125	20,000	--	--	--	20	440	1,000	275	--
Barbco BD160HP	160,000	135	30,000	--	--	--	20	*540	1,200	*325	--
Barbco BD200HP	200,000	110	35,000	--	--	--	20	*600	1,200	*450	--
Barbco BD250HP	250,000	120	45,000	--	--	--	20	*630	1,200	*450	--
Barbco BD380	380,000	100	60,000	--	--	--	35 (random)	700	--	--	--

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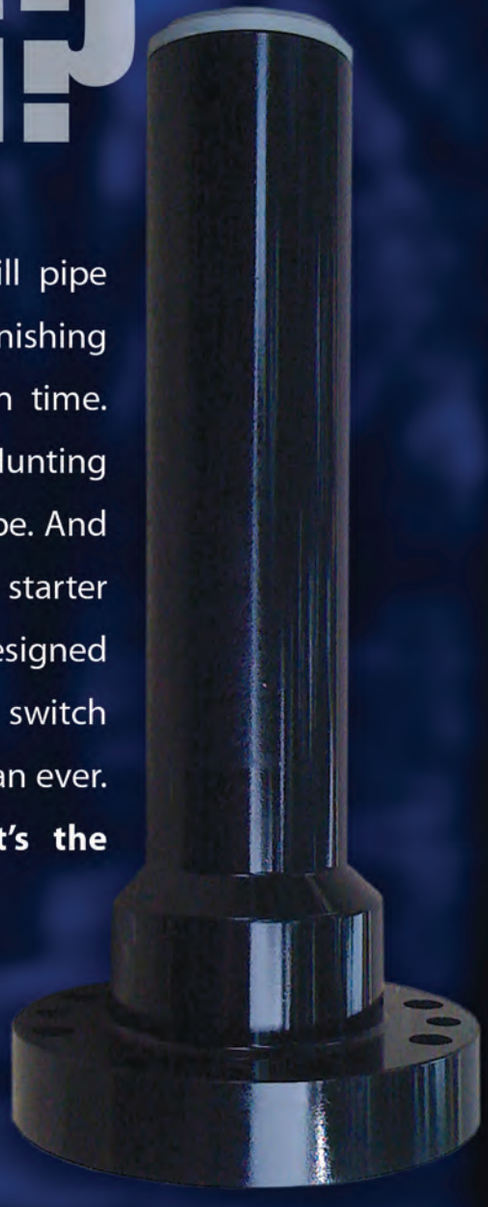

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HUNTING

DITCH WITCH

1959 West Fir St.
P.O. Box 66
Perry, Okla 73077
Ph: (800) 654-6481
Web: *www.ditchwitch.com*

HISTORY

Since its founding in 1949, the Ditch Witch organization has grown from inventing the first mechanized, compact service-line trencher to being a one-stop source for underground construction equipment. With a complete range of equipment for installing utilities underground, the Ditch Witch product line includes trenchers, vibratory plows, backhoes, horizontal directional drilling systems, drill pipe, downhole tools, chain, teeth and sprockets, vacuum excavation systems and mini skid steers. All of these products are recognized around the world for their advanced design, rugged construction, long-term durability, ease of use and reliability. In addition to its line of quality equipment, the Ditch Witch name is trusted for assisting with financial needs. Ditch Witch Financial Services (DWFS) is a full-service provider, offering a wide variety of finance and lease options to meet individual requirements.

PRODUCTS LINEUP

JT5, JT9, JT20, JT25, JT30, JT30 All Terrain, JT60, JT60 All Terrain, JT100 Mach 1, JT100 All Terrain

PRODUCTS SUMMARY

Customers can chose from 10 different Ditch Witch rigs for terrains and conditions ranging from sandy and soft soil to medium and hard soil to soft and hard rock — and the industry's widest range of downhole tooling options come from Ditch Witch to help battle HDD in rocks, mud, tree roots and dense ground. Each HDD model has advanced with customer feedback. Options range from the JT5 with 5,000 lbs of pullback to the JT100 Mach 1 with 100,000 lbs of pullback, and customers can withstand some of the widest ranges of ground conditions with the series of Ditch Witch All Terrain drills (JT30 AT, JT60 AT and JT100 AT). This patented, dual-pipe system has the industry's most advanced inner-rod design, enabling the machine to drill in the widest range of ground conditions, from mixed hard soil to solid rock. The JT5 HDD was modified to meet the specific challenges of shallow installation projects deploying utility lines up to 150 ft. Because the site is often a residential area, the compact JT5 is designed not to disturb driveways, sensitive landscaping and other surface obstacles. Ditch Witch developed the JT25 HDD rig with the utility contractor in mind. The rig combines 27,000 lbs of thrust and pullback with an exclusive rotational drive, which results in a smoother operation and greater uptime on utility backbone installations. The JT100 Mach 1 is the most powerful rig in the our lineup, featuring 70,000 lbs of thrust and 100,000 lbs of pullback, perfect for the long bores used in installations like river crossings. The exclusive dual-pivot drill frame provides outstanding stability and operator comfort.

ADVICE TO BUYERS

When in the planning stages, jobsite variability is the most important thing to consider. Factors to consider include the size of a work area, the type of work being done, the size of bore needed and the type of soil the crew will encounter on the jobsite. Directional drills are used in various applications from burying cable from the curb to a house, to installing a larger-diameter product over several thousand feet.

MAINTENANCE TIP

Maximize your jobsite uptime by performing daily and scheduled maintenance checks because if any part of a rig prematurely wears down, it will affect the overall efficiency of your project.

Co/ Model	Thrust/ Pullback (lbs)	Spindle Speed (rpm)	Torque (ft-lb)	Pilot Bore OD	Maximum Backream (in.)	Maximum Bore (ft)	Drill Pipe (ft)	Engine HP	Maximum Fluid Pressure (psi)	Flow Rate (gpm)	Fluid Tank (gal)
JT5	4,100/5,000	195	550	2.5	4.5	150	4'9"	24.8	750	5	N/A
JT9	9,000/9,000	186	1,100	3	variable	--	6'	66	750	16	N/A
JT20	17,000/20,000	225	2,200	4	variable	--	10'	74.5	1,500	25	N/A
JT25	27,000/27,000	220	4,000	4.02	variable	--	9'8"	130	1,200	50	N/A
JT30	24,800/30,000	225	4,000	4.21	variable	--	9'8"	160	1,500	50	N/A
JT30 All Terrain	24,800/30,000	400	4,000	4.75 (w/Rockmaster 822), 5.5 (w/Rockmaster 86)	variable	--	9'8"	148	1,500	50	N/A
JT60	60,000/60,000	240	9,000	5	variable	--	15	T4i/200 - T3/190	1,300	150	N/A
JT60 All Terrain	60,000/60,000	240	9,000	6.25	variable	--	15	T4i/200 - T3/190	1,300	150	N/A
JT100 Mach 1	70,000/100,000	210	12,000	6	variable	--	14'8"	260	1,000	230	N/A
JT100 All Terrain	70,000/100,000	210	12,000	6.25	variable	--	14'1"	260	1,000	230	N/A

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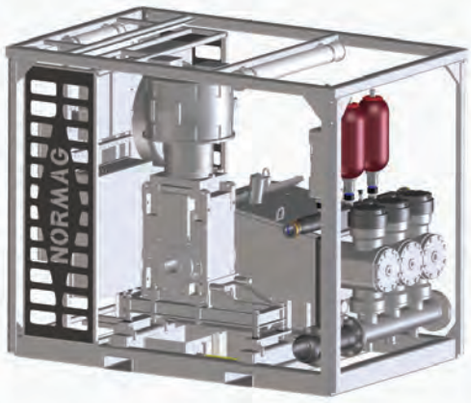

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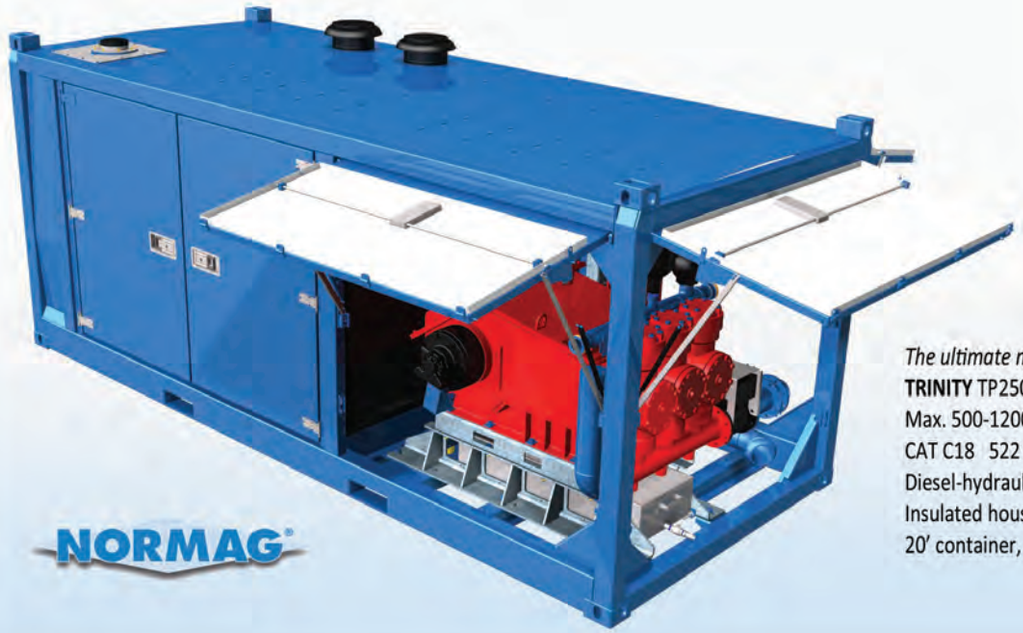

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HERRENKNECHT

Schlehenweg 2, D-77963
Schwanau, Germany
Ph: +49 7824 302-9570
Web: *www.herrenknecht.com*

HISTORY

Martin Herrenknecht founded the Herrenknecht GmbH (limited liability company) in 1977, which became a joint stock company (AG) in 1998. Today, Herrenknecht delivers cutting-edge tunnel boring machines for all ground conditions and in all diameters — ranging from 0.10 to 19 m — and technical solutions to sink vertical shafts, as well as to excavate sloping shafts. In 2013, the Herrenknecht Group achieved a total operating performance of 1,027 million Euro. It employs approximately 5,000 members of staff worldwide including about 200 trainees. In the area of modern trenchless technology, Herrenknecht can look back on almost 30 years of experience on projects worldwide. In addition to HDD, Herrenknecht is continuously developing new technologies for the pipeline industry, e.g. Pipe Thruster, Direct Pipe and Pipe Express.

PRODUCTS LINEUP

Frame Rig, Trailer Rig, Crawler Rig, Modular Rig, Toolings, Tailor-made Solutions

PRODUCTS SUMMARY

The maxi and mega rigs developed and manufactured by Herrenknecht exert pulling forces of between 120 000 and 1 349 000 lbs (600 and 6,000 kN) and achieve a maximum torque of between 35,000 and 110,000 ft-lb, depending on the model. All Herrenknecht HDD rigs have their own diesel-powered energy supply housed in sound-proofed 20-ft containers. The capacity of these power packs, as we call them, can vary from 300 to more than 1,300 hp, depending on the application. These rigs are remarkable not only for their performance capacity but also for their construction design. We offer frame, trailer, crawler and modular rigs. Herrenknecht has collaborated with recognized HDD specialists to develop innovative downhole tools. With these, crossings can be carried out more quickly and economically. We are also specialized in manufacturing tailor made HDD rigs according to customers specification.

ADVICE TO BUYERS

Within the Herrenknecht rental fleet, HDD rigs and other HDD equipment, like Pipe Thruster, High-Pressure Mud Pumps, Mobile Breakout Units etc., can be rented. This enables the client also to test the equipment seriously before buying. Part of the paid rental rates will be considered in the purchase price if the equipment is taken over after a rental contract.

MAINTENANCE TIP

Through our worldwide service network Herrenknecht provides service wherever you are drilling.

Co/ Model	Thrust/ Pullback (lbs)	Spindle Speed (rpm)	Torque (ft-lb)	Pilot Bore OD	Maximum Backream (in.)	Maximum Bore (ft)	Drill Pipe (ft)	Engine HP	Maximum Fluid Pressure (psi)	Flow Rate (gpm)	Fluid Tank (gal)
HK100C	220,000	80	44,250	8 1/2	48	4,000	31.5	443	1,500	600	
HK150C	330 000	72	51,650	9 7/8	48	6,000	31.5	590	1,500	760	
HK150T	330,000	72	51,650	9 7/8	48	6,000	31.5	590	1,500	760	
HK250C	551,000	72	66,400	12 1/4	72	8,000	31.5	644	1,500	1,000	
HK250T	551,000	72	66,400	12 1/4	72	8,000	31.5	644	1,500	1,000	
HK300T	661,000	72	66,400	12 1/4	72	9,000	31.5	644	1,500	1,000	
HK400C	881,000	60	88,500	15	80	12,000	31.5	1,288	1,500	1,200	
HK400T	881,000	60	88,500	15	80	12,000	31.5	1,288	1,500	1,200	
HK400M	881,000	60	88,500	15	80	12,000	31.5	1,288	1,500	1,200	
HK500T	1, 102,000	60	103,300	17 1/2	80	15,000	31.5	1,288	1,500	1,200	
HK600T	1,349,000	60	109,200	20	80	15,000	31.5	1,288	1,500	1,200	

MCCLOSKEY INTERNATIONAL

1 McCloskey Road
Keene, ON, Canada
K9J 0G6
Ph: (705) 295-4925
Email: *sales@closkeyinternational.com*
Web: *www.mccloskeyinternational.com*

HISTORY

Since 1985, McCloskey International has been bringing durable, high production equipment to customers worldwide. In 2014, McCloskey entered the trenchless market with the D15 HDD drill rig as it continued to develop and deliver products that boost productivity and profit for customers. The drilling business was a natural fit. Since 2014, the D15 has undergone extensive design enhancements, resulting from field testing and has evolved into the second generation of the products. Notable in the newest models are the steel shrouds, replacing fiberglass for 2015. Extensive testing revealed that the steel shroud is more durable across a variety of environmental and site conditions. Also available in the new models are stainless steel anti-freeze tanks, which under rigorous testing were better suited to worldwide climate differentials better than plastic. Extensive field testing has resulted in a number of improvements to the operator's station, including enhanced sightlines for the control panel, joysticks angled for comfort, and the placement of the grease bucket on the mast for easier access. Understanding that particularly in urban centers a drill with a small footprint is not only preferred but necessary, the D15 also has re-configured augers to allow greater maneuverability when accessing small spaces. The operator's station has also been streamlined and re-configured to allow for the smaller dimensions, without sacrificing any of the functionality of the drill.

PRODUCTS LINEUP

The D15 has completed field testing and has commenced shipping to dealers in the Middle East, Australia, Europe and North America.

PRODUCTS SUMMARY

Currently the D15 is the latest model is in production. The newly re-designed McCloskey D15 Horizontal Drill Rig sets a new standard in HDD with the most torque and horsepower in the smallest footprint in its class. An advanced electric hydraulic system delivers more horsepower to the ground, better fuel efficiency and guarantees 15,000 lbs of thrust/pullback while simultaneously delivering 1,600 ft-lbs of rotation. McCloskey's Hydraulic Compound Cylinder delivers smoother operational control, high performance and less maintenance. Featuring long life seals and brass wipers for protection from the elements, the D15 requires less maintenance and wear part replacements than other companies' rack-and-pinion design, which can be more at risk for drive motor breaks. The D15 can be started from two locations, with a key start in the back of the rig, and a push button start in the front. An additional feature on the D15 is the open top vise, providing excellent visibility to monitor connections and breakouts. From a safety perspective, the D15 has a number of enhancements to ensure the safe and efficient operation of the rig. Of note, there are three emergency stop, or E-Stop, buttons rather than a limit switch. By moving to a stop vs. limit system, risk is limited that the machine might re-start during rod changes. On the newest version of the D15, sensors have been added to front and back to enhance operator safety, and also to prevent damage. New guards have also been re-designed to cover the augers completely.

ADVICE TO BUYERS

Buyers should look at the operating cost of the rig, and ensure that they are purchasing the best equipment for their application and needs. Buying a rig that is too large to get at small access jobs drives the cost up due to improper application. Request ongoing maintenance information and schedules from the manufacturer to ensure that the rig can be kept in top operating condition. This will ensure the cost of operation is maintained at an optimal level, and the rig stays in the field, not in the shop.

MAINTENANCE TIP

Always walk around the rig prior to start up to make sure all is in working order, especially the e-stop switch. Keeping on track with regularly scheduled maintenance allowa the product a longer life span and less downtime. If the machine is being operated in cold climates, it is recommended that the rig be warmed up prior to operation for enhanced performance.

Co/ Model	Thrust/ Pullback (lbs)	Spindle Speed (rpm)	Torque (ft-lb)	Pilot Bore OD	Maximum Backream (in.)	Maximum Bore (ft)	Drill Pipe (ft)	Engine HP	Maximum Fluid Pressure (psi)	Flow Rate (gpm)	Fluid Tank (gal)
McCloskey D15	15,000 lbs (6803 kg)	130 rpm	1600 ft lb (2200 Nm)	2.5 in/ 63.5 mm	NP	NP	6	59 Hp (44 kW)	1000 PSI / 69 Bar	25 GPM (95 LPM)	NP

MCLAUGHLIN

2006 Perimeter Rd. | Greenville, S.C. 29605
Ph: (864) 277-5870 | (800) 435-9340
Email: *mmole@mclaughlinunderground.com*
Web: *mclaughlinunderground.com*

HISTORY

For more than 90 years, McLaughlin has been an active leader in the underground construction industry. McLaughlin has developed a reputation for designing and building dependable, low maintenance trenchless construction equipment solutions for the power, gas, telecom, water, sewer and oil markets. McLaughlin is focused on developing innovative products that provide contractors safe and productive methods for the identification and installation of underground utilities. McLaughlin offers a full line of utility locators and vacuum excavators for safely finding and exposing existing infrastructure, as well as a number of other trenchless installation products. McLaughlin manufactures Hole Hammer pneumatic piercing tools, Mighty Moles and pit launch directional drills for trenchless installation of conduit, cable and HDPE pipes. In addition, McLaughlin has a full line up of auger boring machines and 360-degree On-Target steering systems for installation of steel casing. Since 1921, McLaughlin takes pride in providing workable solutions for its customers. From planning to installation, McLaughlin offers contractors a complete package for trenchless construction needs.

PRODUCTS LINEUP

McL-10H pit-launched directional drills — 5-ft and 7-ft models

PRODUCTS SUMMARY

McLaughlin offers two pit launch drills: 5-ft and 7-ft models. The 5-ft model is ideal for limited access jobsites and smaller entry pits. This model is very popular in Europe and for use in downtown areas that cannot be accessed with traditional surface-launch directional drills. The 7-ft model is best suited for projects with more access. This model offers enhanced productivity because there is less making and breaking of rods. Both models have 1,030 ft-lbs of torque and 13,250 lbs of pullback. They use a standard locator-transmitter beacon, HDD drill head and HDD tooling. Mud mixing system and hydraulic power pack accessories are also available. Pit-launched directional drills are frequently used by non-traditional HDD contractors. They are straight-hydraulic machines that are simple to operate and very reliable. Like with any piece of equipment, it's important that operators receive proper training and follow standard HDD practices and OSHA regulations for pit set up.

ADVICE TO BUYERS

Before you purchase any piece of equipment, make sure it is appropriate for the application. A pit-launched drill provides a good solution to setback and easement issues but can be more time-consuming to set up than a traditional surface-launched drill. Make sure you understand proper pit excavation, leveling and shoring procedures. Because many users are non-traditional HDD operators, it's also important that they receive proper HDD training to ensure safe and productive operation.

MAINTENANCE TIP

Pit-launched drills are low maintenance machines. Like any drill, it is important to keep the firestick rods greased and to use proper torque procedures to prevent over-torqueing the drill rods. Operators should rotate, or cycle, the rods. This prevents some of the rods from wearing prematurely. Prior to operation, check that the vise dies are in good condition to prevent any slipping during the rod make up or break out process.

Co/ Model	Thrust/ Pullback (lbs)	Spindle Speed (rpm)	Torque (ft-lb)	Pilot Bore OD	Maximum Backream (in.)	Maximum Bore (ft)	Drill Pipe (ft)	Engine HP	Maximum Fluid Pressure (psi)	Flow Rate (gpm)	Fluid Tank (gal)
McLaughlin McL-10H (5 ft.)	17,670/ 13,250 lbs	0 to 125 RPM	1,030 ft-lb	3	12	180 ft	2.4 ft	Hydraulic	1,000 psi	6 gpm	230 gal
McLaughlin McL-10H (7 ft.)	17,670/ 13,250 lbs	0 to 125 RPM	1,030 ft-lb	3	12	180 ft	4 ft	Hydraulic	1,000 psi	6 gpm	230 gal

PRIME DRILLING GMBH

Ludwig Erhard Straße 4
57482 Wenden
Germany
Ph: +49 4489 935 100
E-Mail: *kiesow@prime-drilling.de*
Web: *www.prime-drilling.de*

HISTORY

Prime Drilling is a global leader in the design, development and production of advanced horizontal directional drilling rigs and allied equipment located in Wenden, Germany since 1999. We understand that a successful crossing is particularly dependent on the reliability of the equipment involved. For this reason, it is not enough for us to focus on superior technical characteristics. We are driven to delivery robust, low-maintenance drill rigs that bring top performance in the most demanding environments. Our products and services are backed by a highly qualified team with decades of experience in the field of horizontal directional drilling technologies.

PRODUCTS LINEUP

HDD rigs with pull force from 25 up to 600 tons, pipe pusher, bentonite pumps, mixing units, recycling units, drill rods, reaming tools, measurement equipment and all necessary accessories.

PRODUCTS SUMMARY

We are not only selling "standard" HDD rigs with its components like pumping, mixing or recycling units and reaming tools, drill rods or anything you need for a successful bore. For example, Prime drilling offers also compact rigs. The special feature of our compact rig is the "on board" pump. The PD-X.1.000-C manufactured by our affiliated company Prime-GPT, the specialist for pumps and related spare parts, impresses with its robust and low-wear design. This saves space during transport and onsite and also offers greater flexibility. Another highlight is the Prime Pipe Pusher. The Prime Pipe Pusher mainly serves for additional push or pull force with pipe pullback, but also offers the perfect solution for application combined with tunnel boring machines.

ADVICE TO BUYERS

All our drilling rigs are tailor made to customer's specification: whatever color, equipment or size of the drill pipes you require — any preference will be considered. We are available for our customers at any time: any problems on the jobsite, questions relating to our products or urgent spares requirements — we guarantee 24/7-service.

Co/ Model	Thrust/ Pullback (lbs)	Spindle Speed (rpm)	Torque (ft-lb)	Pilot Bore OD	Maximum Backream (in.)	Maximum Bore (ft)	Drill Pipe (ft)	Engine HP	Maximum Fluid Pressure (psi)	Flow Rate (gpm)	Fluid Tank (gal)
PD 30/18 RP	67,500	43	13,000					190			
PD 45/18 RP	101,000	40	13,000					246			
PD 60/33 RP	135,000	57	24,000					246			
PD 80/50 RP	180,000	38	37,000					326			
PD 100/50 RP	225,000	59	37,000					450			
PD 150/70 RP	337,000	41	52,000					450			
PD 200/70 RP	450,000	41	52,000					640			
PD 250/90 RP	562,000	24	66,000					640			
PD 300/90 RP	674,000	39	66,000					640			
PD 350/120 RP	787,000	30	89,000					775			
PD 400/120 RP	899,000	30	89,000					775			
PD 450/150 RP	1,012,000	46	109,000					775			
PD 500/180 RP	1,125,000	30	133,000					1196			
PD 600/180 RP	1,349,000	30	133,000					1196			
PD 30/18 CU	67,500		13,000					300			
PD 40/22 CU	88,200		16,250					300			
PD 50/30 CU	110,250		22,500					300			
PD 60/30 CU	135,000		22,500					300			
PD 80/45 CU	180,000		33,300					300			

Horizontal Directional Drilling Guide

THE TORO CO.

8111 Lyndale Ave S
Bloomington, MN 55420
Tel: (952) 948-4197
Email: *josh.beddow@toro.com*
Web: *www.toro.com/underground*

HISTORY

Celebrating our first 100 years in 2014, The Toro Co. continues to strengthen its position as a leading worldwide provider of innovative solutions for professional contractors, golf courses, agricultural growers, rental companies, utility companies, government and education institutions and homeowners. Through constant innovation and caring relationships built on trust and integrity, Toro has built a legacy of excellence by helping customers achieve their goals. Toro continues to build upon this legacy by expanding its products and services into new markets. In 2013, Toro launched its new line-up of horizontal directional drills and riding trenchers. Toro's horizontal directional drill and every product that carries the Toro name also carries our commitment to quality and product excellence. Today, contractors around the world count on Toro products to help them their job more effectively.

PRODUCTS LINEUP

DD4045 and DD2024

PRODUCTS SUMMARY

The Toro DD2024 horizontal directional drill packs a powerful 20,000 lbs of pullback force and 2,400 ft-lbs of rotary torque into a compact package. The Toro DD4045 horizontal directional drill combines best-in-class 40,000 lbs of thrust and pullback, and 4,500 ft-lbs of rotary torque with a small footprint (only 85 in. wide). That, along with maximum drilling fluid flow of 70 gpm and tool rotation speed of 225 rpm, gives the DD4045 the versatility to perform a wide range of installations projects. Both the DD2024 and the DD4045 utilize a quad rack-and-pinion carriage design that spreads carriage load evenly and ensures smooth and efficient carriage travel. Additionally, the gear track is welded to both sides of the thrust frame for added reliability. Unique to the DD2024 and the DD4045, the track is propelled by forward-mounted track drive motors with planetary gears, which deliver superior traction in all types of ground conditions. Both the DD4045 and the DD2024 are equipped with a multi-function color LCD display that provides a clear view of machine functions and performance indicators. The operator also has the ability to select single- or dual- joystick operation on either the DD2024 or the DD4045, and can change between the two versions depending on the conditions. Additionally, both units have incorporated heavy-duty, open-top vice wrench designs, which provide excellent visibility of the tool joint from the operator's position. These features all combine to allow the operator to be more productive.

ADVICE TO BUYERS

When determining what size drill to purchase, first consider your business goals. Is the type of installation you expect to be doing in the future different or similar to the installations you're doing today? Plan accordingly — you may want to consider a machine that provides you with the added capabilities to do larger diameter or longer bores if you expect to pursue this type of work in the future. If you're adding drills to your fleet, and adding new operators, also consider features that will help new operators become highly productive — such as the ability to operate a drill using single or dual joystick modes depending on the conditions.

MAINTENANCE TIP

Consider a maintenance plan that includes time for cleaning and a machine inspection at the end of each day. Use the opportunity when applying grease after cleaning to take close look at various areas of the machine. This will allow you to easily identify and resolve maintenance issues in order to be ready for the next day's job.

Co/ Model	Thrust/ Pullback (lbs)	Spindle Speed (rpm)	Torque (ft-lb)	Pilot Bore OD	Maximum Backream (in.)	Maximum Bore (ft)	Drill Pipe (ft)	Engine HP	Maximum Fluid Pressure (psi)	Flow Rate (gpm)	Fluid Tank (gal)
Toro DD2024	20,000	200	2,400	4	NA	NA	400	74	1,500	30	500
Toro DD4045	40,000	225	4,500	4	NA	NA	520	160	1,300	70	1,000

TT TECHNOLOGIES

2020 E. New York St. | Aurora, Ill. 60502 | **Ph:** (630) 851-8200 | **Web:** *www.tttechnologies.com*

COMPANY HISTORY

TT Technologies Inc., Aurora, Ill., is a manufacturer of trenchless technology equipment for the installation and replacement of water, sewer, gas and electric utilities. The equipment is field proven, logging more than 45 years of experience. With more than 200 patents worldwide, TT Technologies is a leader in trenchless applications ranging from pipe pulling, pipe ramming, pipe bursting, sliplining, and directional boring. A nationwide network of regional customer service offices and distribution locations assures products and expertise are always nearby. Comprehensive hands-on training seminars are held at the corporate offices in Aurora, Ill., as well as regional shows, seminars, and demonstrations throughout North America each year.

PRODUCT LINEUP

TT Technologies full line of trenchless equipment includes: Grundomat piercing tools, Grundodrill directional drills, Grundosteer guided piercing tools, Grundocrack pipe bursting tools, Grundoram pipe ramming tools, Grundomudd bentonite mixing and delivery systems, Grundowinch constant tension winches and Grundopit mini-directional drill rigs.

PRODUCT HIGHLIGHT

The compact Grundodrill 4X is designed for residential service, small diameter main installations and "last mile" operations, offering 9,800 lbs of thrust and pullback. Using the compact drill is less intrusive and ideal for areas where larger units are not an option. The drill features a dual hydrostatic pump system and a four-auger stake down system that provides greater stability. The Grundodrill 4X also comes with the exclusive Smart Vice system that performs vice cycling operations automatically.

Co/ Model	Thrust/ Pullback (lbs)	Spindle Speed (rpm)	Torque (ft-lb)	Pilot Bore OD	Maximum Backream (in.)	Maximum Bore (ft)	Drill Pipe (ft)	Engine HP	Maximum Fluid Pressure (psi)	Flow Rate (gpm)	Fluid Tank (gal)
40/60	13,200/8,800	110	662	2.1	4	200	2	23	800	10	225
4X	9,800	230	950	2.5	10	320	5	37.5	800	10	225
15XP	33,047	180	3,262	4	20	985	32.75	142	870	40	2,000
18ACS	40,465/44,961	200	7,375	6.5	24	1,000	32.75	198	870	40	2,000

UNIVERSAL HDD

1221 Flex Ct.
Lake Zurich, Ill 60047
Ph: (847) 955-0050
Web: *www.unihdd.com*

COMPANY HISTORY

With leading position in engineering and production of custom horizontal directional drills and equipment, we are continuing our growth strategy with the new models and product lines at the new state of the art facility. The great demand from the global market of our equipment, our old Ohio facility has reached the limit of its capacity with regards to the production capacities and technological innovation. It was therefore clear that it would not be possible to continue expanding our product line in Ohio. A new production site that would meet the requirements of the brand name Universal HDD had to be found. For Universal HDD the philosophy of creating highest quality equipment and services is not enough. We must continue to push the limits of the industry.

PRODUCT LINEUP

Universal HDD remains to be the leader in design and manufacture of custom horizontal directional drills and equipment. In 2015 we introduced new and upgraded line of rigs: UNI 36x50-15, UNI 80x100, UNI 110x120, and UNI 250x400. These drills feature the most advanced technology in the industry, while maintaining the simple design, high productivity and reliability. Today, more than ever, we are committed to using every resource, to provide the highest quality products and to push industry's standards.

PRODUCT HIGHLIGHT

Our machines have drilled all over the world and in all manner of soil and hard rock conditions. We're not afraid to get our hands dirty. We've worked alongside our customers, making crossings on nearly every continent, under the biggest, widest rivers, and under hill and dale. It is this diversity of environments that has taught us what works best in virtually every type of geology. We've taken what we've learned to design and build the best equipment we know how.

MAINTENANCE TIP

Our customers bank on our extensive knowledge and expertise when they ask us to build some of the toughest, custom designed machines. And they look to us to teach them how to use the equipment, including how to optimize its performance in the field. We assemble a team from Universal HDD and our valued component suppliers and create a training program as customized as our equipment.

ADVICE TO BUYERS

We begin with common platforms, but we engineer and construct horizontal directional drilling machines that meet the specific needs of our customers. Pound-for-pound, at Universal HDD we provide more value to our customers, both in the equipment and customer support.

Co/ Model	Thrust/ Pullback (lbs)	Spindle Speed (rpm)	Torque (ft-lb)	Pilot Bore OD	Maximum Backream (in.)	Maximum Bore (ft)	Drill Pipe (ft)	Engine HP	Maximum Fluid Pressure (psi)	Flow Rate (gpm)	Fluid Tank (gal)
UNI 12x15	12,000	125/250	1,500	2.25			6	66	1,200	27	N/A
UNI 12x15L	12,000	125/250	1,500	2.25			10	66	1,200	27	N/A
UNI 22x22	22,000	160/220	2,200	3.5			10	99	1,200	27	N/A
UNI 30x40	30,000	140/280	4,000	3.5			10	140	1,000	75	N/A
UNI 36x50	36,000	100/200	5,000	3.5			10	140	1,000	75/100	N/A
UNI 36x50-15	36,000	100/200	5,000	3.5			15	140	1,000	75/100	N/A
UNI 70x90	70,000	100/200	9,000	3.5			10	200	963	188	N/A
UNI 80x100	80,000	90/180	10,000	5			15	200	963	188	N/A
UNI 110x120	110,000	70/140	12,000	5			15	275	844	228	N/A
UNI 160x240	160,000	60/120	24,000	5			20	400	844	228/250	N/A
UNI 220x240	220,000	60/120	24,000	6			20	400	844	228/250	N/A
UNI 250x400	250,000	50/100	40,000	6			20/30	450	844	228/250	N/A
UNI 320x500	320,000	50/100	50,000	6			20/30	600	1,100	250	N/A

VERMEER

1210 East Vermeer Rd.
Pella, IA 50219
Ph: (641) 628-3141 or 888-Vermeer
Website: *www.vermeer.com*

HISTORY

Founded in Pella, Iowa, with the invention of a mechanical hoist to help farmers unload grain, Vermeer today serves customers in more than 60 countries with a full line of high-quality underground construction, surface mining, landscaping, tree care, environmental and agricultural equipment. Customers are at the core of the business, and they can expect reliable, local service and support from dealers in more than 60 nations. Vermeer introduced its first horizontal directional drill in 1991. By the end of the decade, the Navigator HDD lineup had become a market share leader worldwide. Today's S3 generation of drills has enhanced speed, simplicity and sound reduction. Vermeer manufactures machines that make a real impact in a progressing world, and the company's HDD line is a significant part of that mission.

PRODUCTS SUMMARY

Vermeer has 15 models of horizontal directional drills in its product line. Eight are intended for utility installation contractors and seven are manufactured for the pipeline market. They range from a 5,500-lb machine to a 1.36 million-lb maxi rig. Features like the DigiTrak Aurora screen give operators more real-time information about their drilling activity. And common control systems across different drills help reduce the learning curve for operators and allows them to be proficient on multiple machines.

Co/ Model	Thrust/ Pullback (lbs)	Spindle Speed (rpm)	Torque (ft-lb)	Pilot Bore OD	Maximum Backream (in.)	Maximum Bore (ft)	Drill Pipe (ft)	Engine HP	Maximum Fluid Pressure (psi)	Flow Rate (gpm)	Fluid Tank (gal)
Vermeer D6x6	5,500/5,500	180	550	N/A	N/A	--	6	25	500	5	N/A
Vermeer D9x13 S3	9,000/9,000	190	1,300	N/A	N/A	--	6	44	750	15	N/A
Vermeer D20x22 S3	19,550/19,550	257	2,250	N/A	N/A	--	10	74	1,000	25	N/A
Vermeer D23x30 S3	24,000/24,000	219	3,000 w/ 2.38", 2600 w/ 2.06"	N/A	N/A	--	10	100	1,300	35	N/A
Vermeer D24x40 S3	28,000/28,000	253	4,200	N/A	N/A	--	10	125	1,050	50	N/A
Vermeer D36x50DR Series II	38,000/38,000	210	5,500	N/A	N/A	--	10	140	1,100	70	N/A
Vermeer D40x55 S3 10' rod	40,000/40,000	227	5,500 w/ 2.63", 5,000 w/ 2.38"	N/A	N/A	--	10	140	1,300 w/ 70, 1050 w/ 50	70 or 50	N/A
Vermeer D40x55 S3 15' rod	28,000 with 2.63", 13,000 with 2.38"/40,000	227	5,500 w/ 2.63", 5,000 w/ 2.38"	N/A	N/A	--	15	140	1,300 w/ 70, 1050 w/ 50	70 or 50	N/A
Vermeer D60x90	60,000/60,000	200	9,000	N/A	N/A	--	15	185	1,200	150	N/A
Vermeer D100x140 S3 15' rod	100,000/100,000	203	14,000	N/A	N/A	--	15	275	1,100/1,000	230/200	N/A
Vermeer D100x140 S3 20' rod	100,000/100,000	203	14,000	N/A	N/A	--	20	275	1,100/1,000	230/200	N/A
Vermeer D220x300	242,100/242,100	164	30,200	N/A	N/A	--	20	415	1,200	330	N/A
Vermeer D330x500	330,000/330,000	88	50,000	N/A	N/A	--	32	486	3,000	--	N/A
Vermeer D500x500	500,000/500,000	36	50,000	N/A	N/A	--	32	800	--	--	N/A
Vermeer D750x900	784,000/784,000	36; 54	102,500	N/A	N/A	--	32	800	--	--	N/A
Vermeer D1000x900	1,000,000/1,000,000	36;54	102,500	N/A	N/A	--	32	800	--	--	N/A
Vermeer D1320x900	1,360,000/1,360,000	36; 54	102,500	N/A	N/A	--	32	800	--	--	N/A

Horizontal Directional Drilling Guide

THE TORO CO.

8111 Lyndale Ave S
Bloomington, MN 55420
Tel: (952) 948-4197
Email: *josh.beddow@toro.com*
Web: *www.toro.com/underground*

HISTORY

Celebrating our first 100 years in 2014, The Toro Co. continues to strengthen its position as a leading worldwide provider of innovative solutions for professional contractors, golf courses, agricultural growers, rental companies, utility companies, government and education institutions and homeowners. Through constant innovation and caring relationships built on trust and integrity, Toro has built a legacy of excellence by helping customers achieve their goals. Toro continues to build upon this legacy by expanding its products and services into new markets. In 2013, Toro launched its new line-up of horizontal directional drills and riding trenchers. Toro's horizontal directional drill and every product that carries the Toro name also carries our commitment to quality and product excellence. Today, contractors around the world count on Toro products to help them their job more effectively.

PRODUCTS LINEUP

DD4045 and DD2024

PRODUCTS SUMMARY

The Toro DD2024 horizontal directional drill packs a powerful 20,000 lbs of pullback force and 2,400 ft-lbs of rotary torque into a compact package. The Toro DD4045 horizontal directional drill combines best-in-class 40,000 lbs of thrust and pullback, and 4,500 ft-lbs of rotary torque with a small footprint (only 85 in. wide). That, along with maximum drilling fluid flow of 70 gpm and tool rotation speed of 225 rpm, gives the DD4045 the versatility to perform a wide range of installations projects. Both the DD2024 and the DD4045 utilize a quad rack-and-pinion carriage design that spreads carriage load evenly and ensures smooth and efficient carriage travel. Additionally, the gear track is welded to both sides of the thrust frame for added reliability. Unique to the DD2024 and the DD4045, the track is propelled by forward-mounted track drive motors with planetary gears, which deliver superior traction in all types of ground conditions. Both the DD4045 and the DD2024 are equipped with a multi-function color LCD display that provides a clear view of machine functions and performance indicators. The operator also has the ability to select single- or dual- joystick operation on either the DD2024 or the DD4045, and can change between the two versions depending on the conditions. Additionally, both units have incorporated heavy-duty, open-top vice wrench designs, which provide excellent visibility of the tool joint from the operator's position. These features all combine to allow the operator to be more productive.

ADVICE TO BUYERS

When determining what size drill to purchase, first consider your business goals. Is the type of installation you expect to be doing in the future different or similar to the installations you're doing today? Plan accordingly — you may want to consider a machine that provides you with the added capabilities to do larger diameter or longer bores if you expect to pursue this type of work in the future. If you're adding drills to your fleet, and adding new operators, also consider features that will help new operators become highly productive — such as the ability to operate a drill using single or dual joystick modes depending on the conditions.

MAINTENANCE TIP

Consider a maintenance plan that includes time for cleaning and a machine inspection at the end of each day. Use the opportunity when applying grease after cleaning to take close look at various areas of the machine. This will allow you to easily identify and resolve maintenance issues in order to be ready for the next day's job.

Co/ Model	Thrust/ Pullback (lbs)	Spindle Speed (rpm)	Torque (ft-lb)	Pilot Bore OD	Maximum Backream (in.)	Maximum Bore (ft)	Drill Pipe (ft)	Engine HP	Maximum Fluid Pressure (psi)	Flow Rate (gpm)	Fluid Tank (gal)
Toro DD2024	20,000	200	2,400	4	NA	NA	400	74	1,500	30	500
Toro DD4045	40,000	225	4,500	4	NA	NA	520	160	1,300	70	1,000

No Trouble with the Curve

Laney Hits Record HDD Run on Houston Ship Channel Install

BY BRADLEY KRAMER

Laney Directional Drilling tallied another record install and did so while handling a tricky curve. Using the intersect method on a 12-in. steel propane pipeline along the crowded ExxonMobil corridor, Laney completed an 11,653-ft installation under the Houston Ship Channel.

Although the horizontal directional drilling operation was a North American record for length using 12-in. pipe, according to CEO Kevin Fox, the bigger challenge was overcoming a 28-degree side bend in the middle of the intersect.

The project was completed in just 23 days by acquiring a rare waiver from ExxonMobil for permission drill 24 hours per day along the right of way, says project manager Kent Lawler. Laney began rig-up operations on Sept. 25, 2014, and completed product pullback on Oct. 17.

NuStar Energy LP contracted Laney as a prime contractor for the HDD operations alone, while WHC Energy Services was the prime contractor for the mainline work. This arrangement is becoming more common in complex HDD projects like this one, Fox says. Typically, HDD contractors are subcontracted by the mainline contractor to perform drilling work.

"When the challenges are as complex as projects like this, the trend used to be from the owners' perspective to have the HDDs performed by a subcontractor who is subcontracted to the mainline contractor, who then assumes the risks of the subcontractor and charges some kind of premium for that risk," Fox explains. "As these more complex projects come about, owners are moving to prime contracting for the drill, as was the case with this project. The mainline contractor had a separate prime contract for pipe work."

Fox says there are potential challenges in terms of communication with this type of arrangement, as the owner must serve as the interface for the two prime contractors to work together in tandem. However, he adds that "All the projects I've seen done like this have been seamless, and no one is delaying the other company."

Expanding Capacity in Texas

The project was part of NuStar's efforts to reactivate a 200-mile, 12-in. pipeline between Mont Belvieu and Corpus Christi, Texas. In the first quarter of 2014, the San Antonio-based company signed a long-term agreement to allow Occidental Petroleum (Oxy) to ship natural gas liquids (NGLs) on the pipeline.

Throughout the last year, NuStar has been working to prepare the line for service, including reversing its flow and converting it from refined products

service to NGL service. The pipeline has a capacity to move approximately 110,000 barrels per day (bpd).

Oxy will use a majority of the line's capacity to transport NGLs via an interconnect with an Oxy pipeline to the Ingleside Energy Center export facility located in Ingleside, Texas, at the site of the former naval base purchased by the company in 2012.

NuStar has continued to market any remaining capacity on the pipeline, which is expected to generate approximately $23 million per year of incremental revenue (EBITDA).

"Our Mont Belvieu-to-Corpus Christi pipeline is one of the key pipelines in our South Texas system, and we are very pleased to have reached an agreement with Oxy to reactivate and utilize the line," said NuStar president and CEO Brad Barron in a Feb. 5, 2014, statement. "The agreement will begin generating distributable cash flow for NuStar in April of this year [2014], and we look forward to exploring opportunities with Oxy and other companies to meet their NGL transportation needs."

Laney's portion of the project involved installing a section of pipeline through the ExxonMobil corridor, under the Houston Ship Channel and into port of Baytown. The only trouble was finding space underground for the pipe, according to Alan Snider, Senior Vice President – Project Management and Engineering. There were more than 15 pipelines in the area where Laney was working.

"Oh it was crazy crowded," Snider says, referring to the challenges Laney faced in designing the project. The engineering team had to sort through the existing pipelines to come up with a design to allow the drilling crew enough footprint to set up equipment.

"Getting accurate as-built records on all the existing lines was a chore," Snider adds. "We went through seven iterations of getting information and then revising the design as we found new or better as-builts. That's what forced us into the 28-degree side bend.

"While it's not the longest project we've ever done, it's definitely the longest with that kind of geometry."

Getting Bent

Laney has performed a number of challenging projects in its past. While none of the challenges — the length, the curve, the intersect — were particularly notable on their own, it was the combination of all three that led to the project being such a challenge.

With a drill this long, Fox says Laney had to use the intercept method, drilling from both sides and then "bump bits" to complete the pilot hole. However, the side bend limited the ability to push the drill pipe, increasing the push load.

Although the drilling operation itself was tricky, Lawler says the biggest obstacle was working in the "highly congested right of way."

"It required substantial engineering work, as there is a lot of infrastructure eating up corridor space," Lawler says. "Our engineers came up with a good route that involved a bend in the channel. ExxonMobil usually requires contractors to be off the right of way by 5 p.m., but we obtained a waiver to work 24 hours. They granted the request due to the magnitude of the project."

Laney received permission to extend its drilling operations to work non-stop thanks to the company's strong working relationship with ExxonMobil, Lawler says. Laney deployed two of its in-house 750,000-lb HDD rigs for the project, using both rigs during the pilot bore and one rig to pull the product pipe into place. The project involved drilling at a total depth of 160 ft and 90 ft below the Houston Ship Channel, through fat clay, lean clay and silty sand.

Employing a design-build approach, Laney got involved with the project early on, performing engineering work for NuStar on the crossing, conducting constructability reviews and performing geotechnical work to reduce the risk of hydraulic fracturing. The company also brought in a drilling mud engineer to ensure the integrity of the drilling hole.

"We planned for 24 hours a day drilling so that the drill pipe was always turning," Lawler says. "If you let the hole sit too long while not working, the hole degrades over time. If you are continuously drilling, it's better for the hole because it stays open and stays lubricated. And ultimately you're reducing the torque on the drill string."

Another challenge was with steering the pilot bore, Lawler says. Because of the heavy ship traffic, Laney was restricted in its use of coil wire for steering and had to rely on other methods, including magnetic locating and a gyroscope.

Pushing the Envelope

As environmental restrictions tighten, Fox says completing these ever more challenging projects helps the industry evolve.

"This technology has only been around since the early 1970s and only became widely used in late 1980s and early 1990s," Fox says. "Even 10 years ago, the technology didn't really exist to take on a project of this length. The old way was to complete two shorter drills with some sort of tie-in in the middle of bay. You would have to use a lay barge in the channel or bay. With environmental regulations ever increasing, we have to continue to push the envelope."

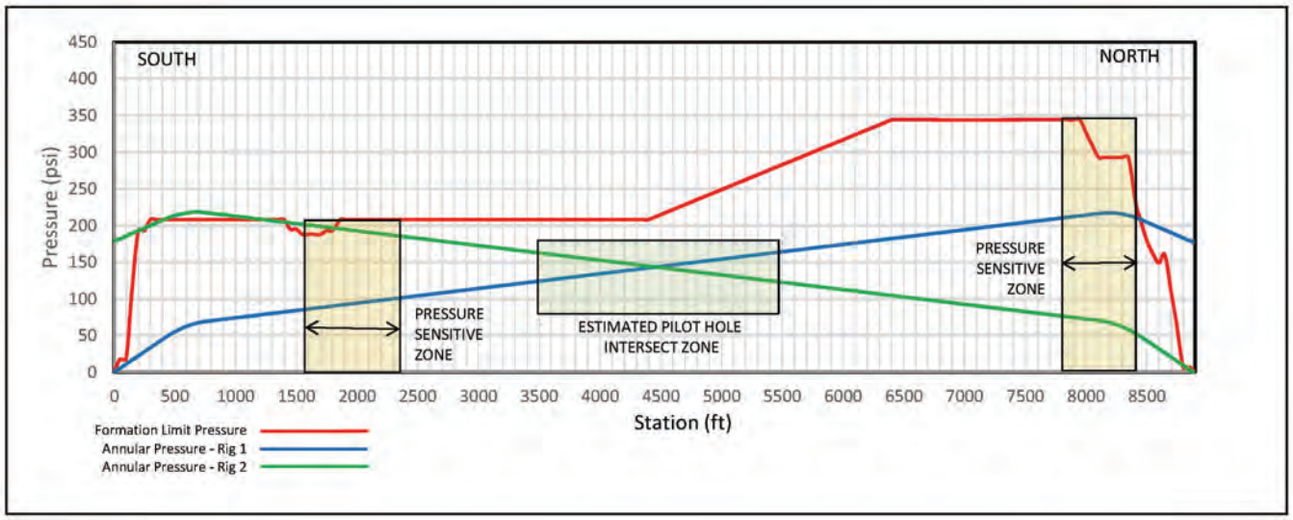
As HDD projects get longer and longer, Fox says contractors like Laney have nearly eliminated the need to disrupt the body of water companies are working under. These newer methods are more environmentally friendly and more economical, as installing a pipeline in one shot like this project eliminates some of the construction costs associated with the earlier methods. Completing these challenging projects also sets precedent in the industry.

"As the industry evolves and crossings get longer, it demonstrates that we've done it before," Fox adds. "Sometimes when an owner contemplates a project like this, it doesn't want to be the guinea pig. We can show them that's it's already been done and make them more comfortable with the risk because they know we can execute the project in a safe manner."

Fox believes that HDD crossings will continue to push the current boundaries.

"The technology exists today to go as long as 15,000 ft. It hasn't been done yet, but I believe the technology already exists to do so," Fox says, adding that smaller diameter pipe will likely be the first, but larger diameters will soon follow. "Sometime in the not too distant future, we'll see larger diameter, 30 in. and above, installed at those lengths with the technology that exists right now."

Bradley Kramer is managing editor of *North American Oil & Gas Pipelines,* a sister publication to *Trenchless Technology.*



Specialized Benefits

Proper HDD Design Is Key to Successful Completion

By Mike Kezdi

The risks for horizontal directional drilling, just like every construction project, increase, as the project's size grows larger, highlight the fact that good designs are imperative to a project's success.

As the acceptance of horizontal directional drilling (HDD) has grown — to the point where HDD is mandated on some pipeline crossings vs. open-cut methods — the companies that specialize in designing HDD projects have seen a shift in a client's knowledge base. Where consultants once had to spend time explaining the very basic of the HDD construction process to a client, many now have been involved with numerous HDD projects throughout their career and have a general understanding of HDD. It is also more common to find an engineer who can design a crossing, but there are benefits to going with a specialist.

"An engineer who specializes in HDD will have a better understanding of what can and cannot be accomplished using HDD. He will have a better understanding of the limits of the technology and the capabilities of HDD contractors," says Jeff Scholl, P.E. engineering manager for J.D. Hair & Associates Inc.

"With our firm, not only do we have extensive practical experience with typical engineering design tasks such as laying out HDD designs, evaluating pipe stress, etc., but we also bring extensive field experience to the table. The advantage of field experience is that you develop a greater understanding of the types of things that can occur, or go wrong, during HDD construction. This knowledge forms the backbone of the engineering judgement we use when designing a crossing."

One of the areas that design engineers who specialize in HDD have focused more attention is in the area of hydraulic fractures and inadvertent drilling fluid returns. The goal of this increased focus is to identify areas where inadvertent returns are likely so that design modifications or other precautions can be taken to minimize the overall environmental impact.

According to Scholl, part of that increased focus is due in part to more rigid requirements and scrutiny from state and federal regulatory agencies. The agencies, Scholl says, like to see the design team taking a proactive approach in trying to minimize the environmental impact associated with HDD. A hydraulic fracture evaluation is one method that can be used to demonstrate due diligence on the part of the HDD designer. It shows that the project team is using all available tools from a design standpoint to minimize the risk of drilling fluid impact to the environment.

"Back in the day, frac-outs were seen as an acceptable, or at least tolerable, consequence of using the technology." Scholl says. "If a frac-out occurred, you contained it, if possible, or in some cases, let it flow freely and continued drilling. Now, with increasing environmental sensitivity, greater efforts are taken both by engineers and contractors in an attempt to avoid their occurrence."

One of the ways this is done is by going with deeper HDD designs. In the last 10 years, Scholl has watched as the industry slowly shift from a minimum design depth of 25 ft or less for a maxi-rig project to 40 ft or more. Adjusting the depth to soils with greater confining capacity is one of the benefits of drilling deeper.

"Another way in which we are attempting to reduce the risk of drill-

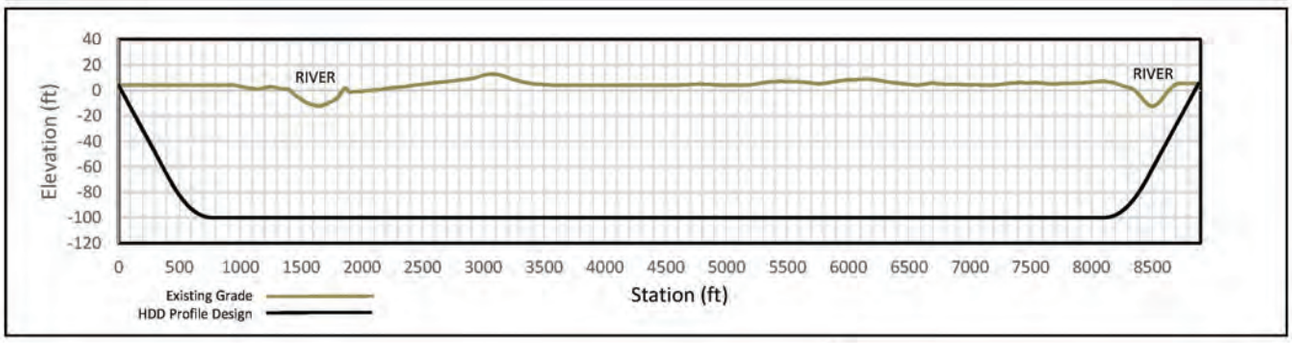


Photo above and left: Hydrofracture evaluation are typically summarized in graphical format. The graphs display the formation limit pressure along the HDD segment vs. the estimated annular pressure necessary for HDD operations. Since the crossing involved a pilot hole intersect, annular pressure curves in two directions are shown.

ing fluid impact is by evaluating annular pressure and assessing the risk of hydraulic fracture of the subsurface. This allows us to identify areas along the drilled segment where there is an increased risk of drilling fluid impact," Scholl says. "You can't always prevent an inadvertent drilling fluid return. If there are naturally occurring fractures in the soil, the fluid will travel in the path of least resistance, so there is not always a way to prevent them. However, by looking at soil types and looking at the annular pressures, there are calculation methods that can be used to predict the risk of a frac-out."

The "Delft Method" is the most commonly used technique to evaluate the allowable drilling fluid pressure. It was developed by Delft Geotechnics and presented in an Army Corps of Engineers publication, titled "Installation of Pipelines Beneath Levees Using Horizontal Directional Drilling" and is widely accepted across the HDD design world, according to Scholl. These calculations also highlight one of the biggest challenges any HDD design engineer faces: Properly quantifying the risk of a difficult crossing.

As the technology in the HDD industry continues to expand, the lengths and complexity of the bores become longer. Though Scholl has no problem with that, he says there is concern when these record lengths are completed and heralded but with little discussion of the numerous complications, delays and disputes that resulted.

"Just because there has been some success with crossings of this magnitude, does that mean other similar crossings should be attempted? What is the risk of failure? Should a crossing be attempted if there is a 1-in-5 chance of failure on the first attempt? What is the client's tolerance for risk? Does the project schedule allow for the significant delays that may result if the crossing is attempted? These are the challenging questions we face," Scholl says. The risk events or operational problems themselves are not all together very different from those encountered during shorter crossings, but the length of the bores magnifies those risks.

Scholl offers this example: With an 8,000-ft pilot hole, even a simple wire line short when 6,000 ft out from the rig, can involve the better part of a week to trip out, repair the wire line, and trip back to the hole face. When compounded on a very long crossing, even small problems like this can significantly increase the duration of a crossing. In the end, the originally estimated duration of a crossing may end up increasing by 100 percent or more. A good design engineer will make the client aware of risks like this during the planning phase.

This is also where an engineer who specializes in HDD can prove to be an advantage to a client. J.D. Hair & Associates, prefers to have an engineer onsite during construction to handle any design issues that may arise.

"A good example would be discovering previously unknown utilities or other obstructions right after the contractor mobilizes to the site. This is particularly true in urban areas," Scholl says. "The field engineer can put together a workable design on the spot or review any changes that are requested by the HDD contractor, thereby avoiding costly standby time."

A second example Scholl offers is daily monitoring of the position and curvature of the pilot hole. The field engineer can review and analyze the contractor's downhole survey data after each shift and verify that the pilot hole is within specification. If a radius of curvature violation is discovered, it can be brought to the contractor's attention the next day, minimizing the amount of re-drilling that may be necessary.

Thanks to increased knowledge, improved geotechnical data and better design software, rare are the days where a contractor receives an undrillable design. Scholl offers one final suggestion. Often overlooked in the design, but crucial to a successful project, is providing the HDD contractor with reasonable pilot hole tolerances. This gives the contractor flexibility to adjust the bore on the fly. Unnecessarily holding the contractor to strict line and grade requirements or strict radius requirements can increase construction duration, cost and public impact.

Mike Kezdi is an assistant editor for *Trenchless Technology*.

MARK YOUR CALENDARS!

Planning Under Way for 2016 HDD Academy

Arizona State University, Benjamin Media Partner for Two-Day Program

Buoyed by the phenomenal success of the 2015 HDD Academy, Arizona State University's Del E. Webb School of Construction and Benjamin Media Inc. (BMI) are once again working together to plan the 2016 Horizontal Directional Drilling Academy (HDD Academy).

Horizontal directional drilling (HDD) is rapidly emerging as the primary choice for owners when confronted with river, road and railway crossings or situations requiring minimal disruption to surface activities. The technique provides a less-disruptive method and, oftentimes, a lower-cost opportunity for utility pipeline installations. The goal of the HDD Academy is to establish an annual learning platform for owners, regulators, contractors and engineers focusing on the options and opportunities for future utility pipeline projects.

The 2016 HDD Academy will take place Feb. 11-12, at the Tempe Mission Palms Hotel, located across from the conference hotel, the Marriott Residence Inn Tempe Downtown. Arizona State University will award 1.8 Continuing Education Units (CEUs) upon successful completion of the course. Registration is limited in order to provide quality networking with HDD industry leaders and maintain a low student-instructor ratio.

Last year's inaugural event sold out and brought together more than 100 HDD experts and contractors to Tempe, all of whom were interested in gaining knowledge about HDD and networking with HDD professionals.

"The success of the 2015 HDD Academy is a testament to the growing strength of the HDD market and thirst for very specific industry education," says BMI president Robert Krzys. "Drillers want good information from experts in the field. They don't want a sales pitch. The HDD Academy is exactly what they are looking for."

HDD Academy program instructors are all industry leaders who will cover numerous topics including HDD contracts and specifications; estimating; designing projects for specific pipe materials; drilling fluids; locating; damage prevention; and case studies covering HDD installations for several pipe materials, Direct Pipe installations and installations for specific utilities.

To date, supporting associations include the Distribution Contractors Association (DCA), Pipeline Contractors Association (PLCA), Pipeline Contractors Association of Canada (PLCAC), International Pipeline and Offshore Contractors Association (IPLOCA) and Association of Equipment Manufacturers (AEM). Event sponsors to date include Herrenknecht Tunneling Systems, Underground Solutions Inc., Vermeer and Derrick.

Benjamin Media Inc is a multi-faceted business-to-business media company in markets ranging from construction to water infrastructure. It is dedicated to meeting the expectations of its readers, advertisers, vendors and all stakeholders in the markets it serves. BMI has found success identifying and promoting emerging markets through quality publications and in-

novative exhibitions and conference programs. BMI currently publishes eight trade magazines: *Compact Equipment, NASTT's Trenchless Today, North American Oil and Gas Pipelines, Solar Builder, TBM: Tunnel Business Magazine, Trenchless Technology, UIM: Water Utility Infrastructure Management* and *Utility Contractor*.

The Del E. Webb School of Construction (DEWSC) is housed within the Ira A. Fulton Schools of Engineering at Arizona State University and is one of the top Construction programs in the country. Established in 1957, the DEWSC is home to Construction Management and Construction Engineering degree programs. Currently, there are 17 full-time faculty members and over 400 undergraduate and graduate students in the School. This past July, the DEWSC moved into a new $55 Million, 130,000 sq. ft. state-of-the art facility in Tempe, Ariz.

For more information, visit *hddacademy.com*. For sponsorship opportunities, contact Brittany Maurer at *bmaurer@benjaminmedia.com*.

The 2015 HDD Academy sold out and brought together more than 100 HDD experts and contractors, allof whom were interested in gaining knowledge about HDD and networking with other HDD professionals.

HDD in Montana

Horizontal directional drilling (HDD) technology has advanced dramatically in the past two decades. Projects once considered impossible are completed routinely, and acceptance of HDD by design engineers and project owners has reached levels where HDD often is the preferred method of construction, even in conditions where excavation is an option.

Horizontal directional drilling may have become commonplace, but some projects stand out from the hundreds being done each year — those that generate special note includes those that are long, deep bores to pull back large-diameter product. Long water crossings are among the most interesting, attention-getting and talked about projects that are done in the industry.

Michels Pipeline Construction recently completed a 2,350-ft-long bore under the Milk River in Montana to install 12-in. diameter steel gas line to replace an older segment of pipe. The bore path was 35 ft beneath the river bottom and parallel to an existing pipeline.

"There was ample room to set up the drill rig to launch the pilot bore, weld the pipe and plenty of work space at the exit end, also," said Rob Healy, Michels senior project manager. "Width of the river at the crossing was 80 ft. The length of the bore was determined by distance needed to achieve the required depth to go under the river and come up to the exit point. Minimum radius of the bore path was 1,200 ft."

A Ditch Witch JT100 All Terrain (AT) model drill rig was used to complete a 2,350-ft-long bore under the Milk River in Montana. A 12-in. diameter steel gas line was installed to replace an older segment of pipe.

Project Challenges

Healy described subsurface conditions as "difficult," composed of sandstone and clay stone.

"We used a 6-3/4-in. tri-cone bit for the pilot hole and used walkover tracking equipment," said Healy. "We did not need a boat for tracking — we were able to locate by wading into the river."

The first pass was made with a 16-in. tri-cone reamer and the second pass was made with a 20-inch hole opener. Pullback was complete in one day.

A Ditch Witch JT100 All Terrain (AT) model drill rig was used, powered by a 268-hp diesel engine. In addition to 100,000 lbs of pullback, the machine develops 12,000 ft-lbs of rotary torque.

Ditch Witch AT equipment uses a mechanical, dual-pipe drilling system with an inner rod to drive a rock bit and an outer pipe to steer the downhole housing and to provide rotary torque for the hole opener during backreaming. The

system delivers maximum available power to the downhole tool for drilling through solid rock, fractured rock, and mixed soil conditions. Because the drilling system is mechanical, AT equipment requires no more drilling fluid than conventional equipment.

"The primary challenge to this crossing was the tough soil conditions," concluded Healy. "From set up to demobilization, the project was completed in 26 days."

Michels Pipeline Construction is a diversified pipeline construction contractor with the experience, expertise, personnel, and equipment to perform every phase of pipeline construction. It is a division of the Michels Corp. which provides construction, engineering and procurement services for the energy, transportation, telecommunications and utility construction industries. Michels is based in Brownsville, Wis. Michels offers a wide range of HDD services with an industry leading fleet of equipment and experienced personnel.

Ditch Witch, a Charles Machine Works Co., invented the underground utility construction industry, and today it designs, manufactures and markets a complete line of directional drills, drill pipe, HDD tooling, vacuum excavators, trenchers, chain, teeth and sprockets, mini-skid steers and vibratory plows. Handcrafted in the United States, its products are supported by the Ditch Witch dealer network with more than 175 locations worldwide.

Established in 1902, Charles Machine Works, an employee-owned company, founded in Perry, Oklahoma, is the only manufacturer and global distributor that solely exists to make underground utility construction profitable. Its family of brands includes Ditch Witch, Subsite Electronics, DW/TXS, HammerHead, Radius HDD, American Augers, Trencor and MTI Equipment.

This article was provided by Ditch Witch.

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Powering Car Production with Landfill Gas

Contractor Installs Transmission Lines for Toyota Green Energy Project

BY GREGG HENNIGAN

Environmental initiatives from car manufacturers typically focus on developing vehicles that run on renewable fuels. But Toyota is going beyond that by turning to green electricity to help power a massive Kentucky plant that makes cars, including hybrid models.

The project by Toyota Motor Mfg., Kentucky Inc., will convert landfill gas, which is normally burned off as waste, to electricity and transfer it to its assembly plant in the town of Georgetown.

To get the electricity from the landfill to the plant nearly seven miles (11.3 km) away, Toyota turned to G&W Construction to install transmission lines. The utility contractor had to drill and trench through hard Kentucky limestone to get the job done, but owner Darrell Alderman says it was well worth the effort in order to be part of a project with a major company that will help the community and the environment.

"That makes it that much more exciting to work on it," he says. "It's great to be working on a green project where you know that this energy is not just burnt off and wasted but is going to be used to create electricity."

Gas Becomes Electricity

As solid waste decomposes, a gas that is roughly half methane and half carbon dioxide is produced. The gas often is flared off at landfills.

Landfill gas can lead to smog, harms the atmosphere and contributes to climate change. In many cases, however, it does not have to be flared and can instead be captured and converted to energy.

As of March, there were 645 operational landfill-gas energy projects in the United States, according to the U.S. Environmental Protection Agency, adding that another 440 landfills were candidates and would produce enough electricity to power nearly 512,000 homes. The agency calls using landfill gas for energy a "win/win opportunity" that destroys methane, generates renewable energy, reduces air pollution and creates jobs.

The Central Kentucky Landfill in Georgetown, which is just outside Lexington, is one of the latest operations to accept that win-win premise. Toyota teamed up with landfill owner Waste Services of the Bluegrass on the landfill gas-to-energy project.

The Georgetown facility is Toyota's largest vehicle manufacturing plant in North America. It is 7.5 million sq ft (696,773 sq m), sits on 1,300 acres (526.1 ha) and employs more than 7,500 people. Last year, it produced its 10 millionth vehicle since opening in 1988.

Toyota reports that the landfill gas system will generate 1 megawatt of electricity an hour, which is about what it takes to power 800 homes. In actual use, the electricity will power the production of 10,000 vehicles a year. Also, greenhouse gas emissions from the landfill will be cut by as much as 90 percent, the company says.

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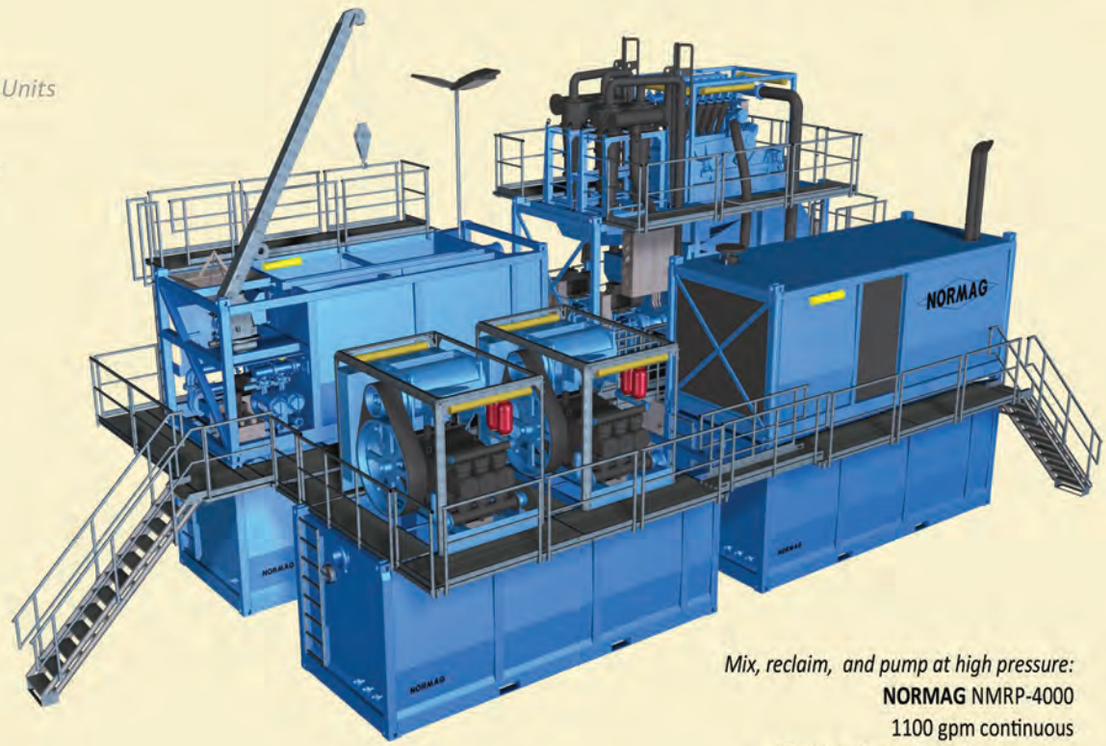

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"As a corporate citizen of central Kentucky, we are committed to smarter and better ways of doing business to enhance our community and environment," says Todd Skaggs, CEO of Waste Services of the Bluegrass, in a news release. "We look forward to being a partner in Toyota's sustainability efforts."

Once finished, a network of wells at the landfill will collect and prepare the gas, which will be used to fuel generators to produce electricity, according to the news release. Underground transmission lines will then carry the electricity to the Toyota plant to the south.

'Heavy Artillery' Installs Conduit

G&W Construction was tasked with installing those lines over 35,000 ft (10,668 m). The company, located about an hour's drive east of Georgetown in the town of Morehead, started work in December and finished the following spring.

The specs from Toyota called for the use of horizontal directional drilling on about 23,000 feet (7,010.4 m) of the installation, most of it in residential neighborhoods. The rest was installed by a track trencher in a rural setting.

The crews were pulling three 2.87-in. (7.3-cm) conduits with the electric transmission line in them. The HDD work called for bores with a diameter of 7.5 in. (19.1 cm) ranging from 1,000 to 1,500 ft (304.8 to 457.2 m) in length, and a minimum cover of 48 in. (121.9 cm). With the track trencher, they were cutting 48 in. (121.9 cm) deep and 14 in. (35.6 cm) wide.

Georgetown is in north-central Kentucky, which is notorious for its limestone. The rock is hard and takes more time to cut through, and it can be rough on equipment. Alderman says there was a relatively thin layer of clay on top and then the crews had to work through limestone of around 12,000 psi (827.4 bar).

"It was pretty much a no-brainer that we were going to have to have some pretty heavy artillery to get this in," Alderman says.

G&W Construction used two Vermeer D100x140 Navigator horizontal directional drills and a Vermeer T655 Commander 3 tractor with a trencher attachment. Two HDD crews operated simultaneously and leapfrogged each other as they completed bores.

THE CREWS WERE PULLING THREE 2.87-IN. (7.3-CM) CONDUITS WITH THE ELECTRIC TRANSMISSION LINE IN THEM. THE HDD WORK CALLED FOR BORES WITH A DIAMETER OF 7.5 IN. (19.1 CM) RANGING FROM 1,000 TO 1,500 FT (304.8 TO 457.2 M) IN LENGTH, AND A MINIMUM COVER OF 48 IN. (121.9 CM).

They were able to bore 2,000 to 3,000 ft (609.6 to 914.4 m) per week during the winter.

Because of the limestone, they used a 5.75-in. (14.6-cm) diameter hammer drilling system for the pilot bores and did not need to backream. The hammer system can fracture rock and made a large enough hole that backreaming was not required.

"The limestone is layered, and in layered rock the steering is a little more of a challenge," Alderman says. "So we just drilled it and hooked to the conduit and pulled it back, which really saved time."

For its drilling fluid needs, the company used a Vermeer MX240 drilling fluid system and a Vermeer by McLaughlin vacuum excavator.

On the open-cut portion of the job, the trenching crew installed an average of about 500 ft (152.4 m) of conduit a day. They used a chevron formation for the trencher teeth to cut through the limestone. It's a more versatile pattern in solid or chunky layers and one G&W Construction previously had success with in similar conditions, according to Alderman.

Meeting Industry Challenges

Alderman says the project was an example of how important equipment is in today's underground industry. G&W Construction has been in business for half a century, since Alderman's father started the company to construct commercial buildings. These days, it specializes in underground utility installation, and Alderman says increased competition is shaping the industry. That makes bidding on jobs a bigger challenge than ever, and Alderman says a successful company must have the right equipment to work as efficiently and as productively as possible.

The Toyota job had tough ground conditions with the limestone and a tight deadline, and G&W Construction worked for a major company on a cutting-edge project that will turn landfill gas into energy.

"We were proud to be selected by Toyota to do this job," Alderman says. "Then the production we were getting made it that much sweeter. It was just a real neat challenge."

Gregg Hennigan is a features writer for Two Rivers Marketing, Des Moines, Iowa.

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Large-Diameter Restrained-Joint PVC Pipe Helps Chicago Suburb Get Relief From Sewer Backups

By Chris Aldred

Faced with boring through wetlands and under a creek to address much needed improvements to its sanitary sewer system, the City of Elmhurst, Ill., turned to new large diameter restrained-joint PVC pipe and horizontal directional drilling (HDD) to get the job done.

After area homes were plagued with sanitary sewer backups following a severe storm in 2010, the Chicago suburb launched the $10 million Southwest Elmhurst Wet Weather Control Facility project. This was not the first time the City had faced storm-related backflow problems, and the new project aimed to alleviate sewer backups in as many as 2,300 homes in the southwest corner of the City, the area hit hardest by sewer backups.

The initiative included the installation of a deeper, 24-in. gravity sewer line that can accommodate higher flow rates delivered to an upgraded lift station, which includes larger pumps, enhanced controls and an expanded wet well. From the station, sewage is currently pumped by way of a 10-in. dry-weather force main to the existing gravity interceptor. A new 18-in. wet-weather force main is also being constructed that zigzags beneath the City toward a new, 2 million-gal storage tank at the city's Water Reclamation Facility.

The main goal of the City and its engineers was to divert excess sewage generated by extreme weather from entering and overwhelming the Water Reclamation Facility and causing sewer backups in area homes. They knew they needed the larger diameter pipe, but also had to contend with the challenges of working in a residential area and boring in difficult ground conditions.

Catherine Morley, P.E., senior project manager with RJN Group of Wheaton, Ill., explained that in order to address the problematic sanitary overflows, the City needed to approach its sewer system in a new way.

"Essentially, we redefined the pump station by making it both a dry weather and wet weather station," she said. "We will still pump the sewage to the interceptor during small rain events via the dry-weather force main, but when that interceptor is overloaded during extreme conditions the addition of the 18-in. force main and the above-ground storage facility will enable the station to pump higher flows without overloading the Water Reclamation Facility and downstream sewers."

Morley says it took a good deal of planning to figure out how to essentially divert large volumes of excess flow from the City's residential area to the treatment plant and storage facility. "To get there was tricky because we would be working in residential areas and having to cross a creek to reach the treatment plant, we had limited routes with which we could work," she said.

The City needed 5,000 ft of 18-in. force main; however, a good portion of this line would have to run beneath flood plain, under levees and cross under a creek and wetlands. For these more sensitive areas, RJN specified nearly 2,000 ft of 18-in. Certa-Lok C905 restrained-joint specialty PVC pipe from North American Pipe Corp. (NAPCO) to be installed via horizontal directional drilling.

"We were required to bore through wetlands because the open-cut method is not feasible in these areas. Part of the project also required the pipe to go under Salt Creek, and the county required we bore that part of the project, as well," explained Garry Sementa, project manager with Archon Construction Co. Inc., of Addison, Ill.

Morley said they chose Certa-Lok PVC pipe for its ability to hold up in the unstable ground of the wetlands. Its easy-to-assemble restrained joints would also prove useful because the crew had limited space in which to assemble the pipe when working near the creek. Fortunately NAPCO had recently begun manufacturing the time-tested Certa-Lok pipe in an 18-in. size, which was a perfect solution for this project.

Certa-Lok C905 RJ is the industry's original non-metallic, mechanically re-

strained-joint piping system designed for use in force main sewer systems, water and other applications. It utilizes precision-machined grooves on the pipe and in the coupling which, when aligned, allow a spline to be inserted, locking the pipes together. A flexible elastomeric seal, or O-ring, in the coupling provides a hydraulic seal. This is the first time Elmhurst's superintendent of water and wastewater distribution Christopher Dufort has worked with Certa-Lok.

"It's been a learning experience for me. Seeing how it works. I was pretty amazed at how well it operates and how much force you can use to pull those pipes together with their spline. I'm impressed so far. We did three bores with it and it worked out great," he said.

The drills that ran the Certa-Lok force main beneath the berms, the creek and the wetland were undertaken in typical fashion. At each of those sites, Archon Construction set up the boring machines, drilled the hole, treated it with bentonite drilling fluid, reamed it, then pulled the pipe through. Vacuum trucks were nearby to extract sludge and slurry. The creek, however, was a little different.

This phase of the project totaled more than 1,000 ft. The crew initially installed 165 ft of 30-in. steel casing beneath the creek for protection, which is a county requirement. To bore the pipe, the crew dug pits on either side of the creek, with the access pit about 800 ft away on the east side, outside of the flood berm. The crew bored the initial hole, then during pullback it installed the casing spacers onto the last 170 ft of the Certa-Lok. This work was done while the crew was 15 ft deep in the entry pit with only 40 ft available to prepare the final sections of pipe for insertion into the casing. During this final phase, the crew pushed the Certa-Lok joints close to their maximum tolerance, reaching 67,500 lbs pull pressure at times.

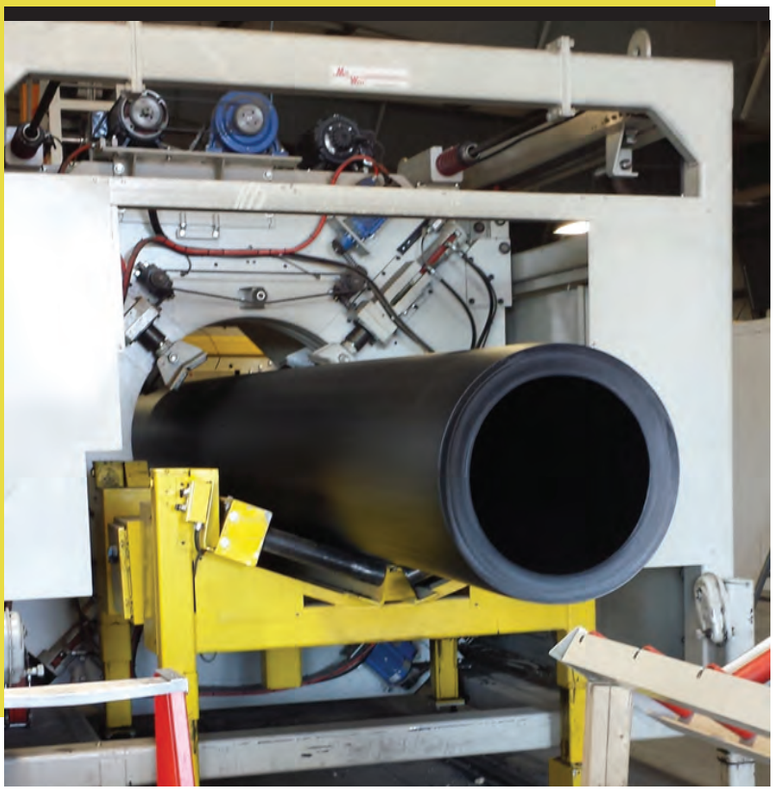
"The limited amount of space we had to work on the west side of the creek to get the pipe back to elevation was interesting," Sementa said. "Certa-Lok's ability to bend was a huge benefit in this case, and everything held together."

Morley agreed. "It is a great pipe. This is the fourth project in which we've used Certa-Lok. In this project, especially where we needed shorter lengths, it was ideal. The standard length is 40 ft but for some of the installs the manufacturer provided 20-ft pipe sections. We had limited space in which to work so we needed a pipe that we wouldn't need to be fused together," she said.

This phase of the Southwest Elmhurst Wet Weather Control Facility project was expected to be completed in June. The City expects the entire project to be up and running in 2016, when the team completes the pump station and storage tank.

Chris Aldred is with North American Pipe Corp.

HDD Deep Under 'Ring Road' Saves Highway



By Steve Cooper

Boring down nearly 11 m (36 ft) enabled a new potable water pipeline to be installed in 14 days without disrupting above ground construction or soils by trenching, which could cause unwanted settlement of the new ring of multi-lane roadway.

To serve the City of Edmonton, Alberta, Canada, an existing potable water service line had to be connected under the North East Anthony Henday Drive (NEAHD) ring road. When completed in late 2016, the $1.8 billion ($818.8 million U.S.) highway project will connect the northwest and southeast parts of Anthony Henday Drive from Manning Drive to Whitemud Drive East. Work includes the construction of 27 km (16.7 miles) of six- and eight-lane divided roadway, nine interchanges, two road flyovers, eight rail crossing (flyovers) and two bridges across the North Saskatchewan River, for a total of 46 bridge structures. Using the Public-Private Partnership (P3) process, it is anticipated that the road will be finished three years earlier than through conventional methods.

The 549-m (1,800-ft) pipeline needed to be monolithic and joint free to reduce the risk of any issues such as leaks, joint separation or other problems that can be found with traditional products and materials. Operating pressure is 200 psi.

The decision was made to use horizontal directional drilling (HDD) for the pipeline using 450-mm (18-in.) diameter DR 11 PE4710 high density polyethylene (HDPE) pipe from WL Plastics, of Fort Worth, Texas. The drill was through clay and gravel substrates, which posed a challenge but was successfully completed. Each end of the drill involved reconnecting the HDPE to existing ductile iron and PVC bell and spigot water mains. Because of the soil conditions, overall length and depth of the installation, it was decided that there would be inspections and monitoring milestones throughout the course of the project.

This was a deep bore that hit a few voids along the way. The soil is mostly clay but the HDD crew would hit pockets of sand that would cause the head to drop. The reamer head weighed about 1,600 lb and would drop when it got to that wet, silky material and was hard to hold it on the path. Different kinds of drilling mud were used to solve the problem.

The crew made several passes until the final 450-mm (18-in.) HDPE pipe was pulled. The first was 6.5 in. followed by 18 in. and ending with 28 in. on the last bore.

Four milestone inspections were established for the construction process in order to raise confidence in line construction to help ensure a problem free system. They were categorized as:

1. Inspection of the pipe during and after the delivery and unloading at the work site.
2. Monitoring and recording of all fusion conditions, fusion processes (including pipe staging area) and assembled storage.
3. Monitoring of the pipe pulling process once pilot holes where completed via HDD.
4. Monitoring of the pressure testing and disinfection process.

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Safety aspects and milestones expectations were reviewed, communicated and responsibilities assigned prior to starting any process for handling, assembly, installation and testing. This provided clarity for individual responsibilities, timing, accountabilities and what to do if unusual circumstances occurred.

WL Plastics was asked to assist in monitoring all these milestones. When the aspects of design, manufacturing, handling and installation are conducted in accordance to specified industry design and procedures, the life cycle of HDPE installations, according to WL Plastics, will meet or exceed expected service lives, which reduces costs for generations to come.

The 18-in. diameter (450-mm) IPS DR 11 PE4710 line required product approval in accordance with the local utility's construction standards. The pipe was produced at the WL Plastics Calgary, Alberta plant in accordance with ASTM F714, AWWA C906 and Factory Mutual requirements. The WL Plastics pressure-rated PE4710 pipe is manufactured from engineered polyethylene compounds (WL106B) that provide a balance of short-term and long-term properties for pressure-pipe applications. The PE4710 pipe resists pressure surges, handling and installation, soil subsidence, frost heave and seismic displacement.

The 549-m (1,800-ft) PE4710 pipeline had no lateral connections but needed to be connected to both existing steel and bell and spigot PVC at either ends.

For the PE4710 pipe sections, there were 36 fusions, which where all data logged, monitored and inspected for consistency. Each fusion included proper cleaning of the pipe, properly aligning pipe in fusion machine, closely checking the pipe after facing, cleaning and measuring both sides of heater plate, monitoring heat soak and heat bead formation, visually inspecting every heated fusion interface once the heater plate was removed, bead formation once interfacial pressure was applied and cooling times with consideration for warm ambient conditions.

Once the pipe was properly cooled and removed from the fusion machine the length of pipe was pushed out and placed on rollers to protect against scouring or gouging and also to reduce friction forces when pulling the pipe through the boarded hole. After the entire line was fused together and inspected one last time, the drill was pulled back.

The HDD crew made several passes until the final 450-mm (18-in.) HDPE pipe was pulled.

Once installed, a minimum period of 24 hours was provided to allow for any "pull back" or "shrinkage" of the pipe prior to reconnecting to existing ends.

"The higher performance of this PE4710 pipe provides a very durable system due to its improved properties," said Camille Rubeiz, P. E., director of engineering for the Plastics Pipe Institute Inc.'s Municipal Division. PPI is the major trade association representing all segments of the plastic pipe industry.

"It is designed for water and wastewater applications meeting AWWA C906 and ASTM F714 standards and because it is strong and durable, it is the material of choice for trenchless applications such as HDD, sliplining and also for pipe bursting."

Once stabilization of the pipe length was finished, the pipe was connected to the existing ends and filled with water. The final stage of the installation was the pressure testing of the newly installed HDPE section. Hydrostatic pressure testing was conducted once the line was filled with water and all air was removed from the system. It was pressure tested to ensure no leakage or pipe separation had occurred during installation. Once stabilized the pressure was held for an hour to ensure no leaking occurred. None occurred over the entire 1,800 ft or in any of the 36 fused joints, and the line was approved for operation.

"The benefits of this installation is that HDPE piping is considered leak free and corrosion resistant," explained Richard Kolasa of WL Plastics and a certified engineering technologist, plastics and polymer engineering. "For the NEAHD millions of infrastructure dollars were spent on the 'ring road' highway, therefore digging open trenches and ripping up the road was impossible. Plus the project required a pipeline with high integrity that would last for many years."

"The other benefit was the installation itself. Cost reductions were realized because the open trench would have been close to 20 m (65 ft) in depth and wide. Using HDD there was hardly any evidence that the new pipeline was installed. In addition to the labor, backhoes, trucks and use of trench boxes, excavating a deep trench caused concern of settling soils under the roadway. The last real benefit for PE4710 pipe is the resistance to surge events and freezing resistance. We are extremely confident that the new PE4710 water transmission line section under the North East Anthony Henday Drive will provide reliable flows and a maintenance-free system for many years to come."

Steve Cooper has been reporting on the water and pipe industries for several decades.

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SAFE EXPOSURE:

Uncovering the Benefits of Hydro Excavation

By Tisyn Milne

With millions of kilometers of buried utilities beneath Canada's surface and records inaccurate or incomplete, it is surprising that there is not more property damage and personal injury occurring every time somebody puts a shovel in the ground. Even backyard landscaping can cause millions of dollars in damage when utility lines get hit, service is interrupted and expensive repairs have to be undertaken.

One can only imagine the ten-fold risk and additional expense when it comes to large scale infrastructure projects taking place across Canada. In a 2011/2012 report by Statistics Canada it was revealed that 40 percent of all damages to underground infrastructure occur due to a failure to notify, a frightening 84 percent of damages cause a service interruption, and 75 percent of all damages are due to outside force through usage of a backhoe or mechanical excavation.

In recent years, many initiatives have focused on mandating safer installation, exposure, maintenance

While the One Call System is a good starting point to identify a utility's location, properly exposing the infrastructure is the only sure way to know where it truly lies, and how the pipe or wire has been run.

and repair of buried utilities. While the One Call System is a good starting point to identify a utility's location, properly exposing the infrastructure is the only sure way to know where it truly lies, and how the pipe or wire has been run. This is where hydro excavation comes in as an essential tool of visually locating utilities to mitigate the risk of striking underground infrastructure.

With current government regulation prohibiting the use of mechanical means to dig within 45 cm of buried cables or pipes, hydro excavating is an ideal method to expose underground infrastructure, drill pile holes, trench slots, install signs and poles and conduct landscaping and potholing.

A Vital Industry

What is standard practice in Canada today, began more than 50 years ago in the Alberta oil and gas fields where hydro excavation machines were used to 'daylight' buried gas pipes and other utility lines. Cold weather, and even permafrost, would only allow year-round excavation by using heated water, which made Hydro Excavators all the more popular.

When customers began modifying vacuum trucks and sewer cleaners for hydro excavation use in the 1970s and 1980s, and even mounted vacuum components on all-terrain vehicles to get into remote locations the demand was recognized and the manufacturing of dedicated truck-and-trailer-mounted hydro excavation units began in the 1990s due to the growing demand.

The millennium hit, and hydro excavation was already widely accepted and used by utility contractors across Canada for locating and non-destructive digging. It was around that time, that Illinois-based Vactor Mfg. introduced its first dedicated HXX Hydro Excavator as a purpose-built unit and became a leading manufacturer for this ever-growing market.

Today, hydro excavation is considered to be a best practice by municipalities, contractors and public utility organizations alike. As the HydroVac Alliance of Ontario (HVAO) together with the Ontario Regional Common Ground Alliance (ORCGA) indicate in a recent report, the size of Ontario's hydrovac market has grown significantly since the first custom-built hydro excavators appeared. The associations estimate that there are between 450 and 500 units in operation across Ontario responsible for a total annual revenue of $180 million to $200 million.

Extremely versatile, hydro excavators can be seen virtually on every street corner where they drill holes for fence posts, poles and signs or conduct daylighting of underground gas pipes. And once you see a hydro excavator in action, you will never forget the efficiency and power this unit demonstrates while completing a job. A recent study by the City of London says it best: "…The hydrovac unit effectively replaced the hand digging requirement being completed in 1/3 of the time and with 1/2 of the crew. The cost of using a shovel and backhoe compared to a hydrocvac unit on the identical job is 4.1 times greater."

Born To Run

As hydro excavation becomes more and more popular, the importance of zero downtime applies to most hydrovac companies to ensure they can keep up with the day-to-day demand for their services. Industry veterans such as the Toronto-based PGC Services Inc. (PGC), a member of the Powell Group of Companies, trust a full service shop of the likes of Joe Johnson Equipment for new purchases, rental units, used equipment and to regularly service and maintain their hydro excavating equipment.

Regular inspections do not only benefit operators and customers, increase safety and are better for the environment, but they also lead to higher resale and trade-in values based on the service history.

In search of a safe, cost-effective and non-disturbing option to expose underground infrastructure when performing an excavation project, the past 30 years have seen a major shift to move from backhoe digging to hydro excavating. Associations such as the Canadian Common Ground Alliance (CCGA), the Centre for Advancement of Trenchless Technologies (CATT) and the members of the HVAO have become important advocates in promoting safe digging procedures, and with the increasing use of hydro excavation, Canada leads the pack as a nation that knows how to safely deal with its underground infrastructure.

Tisyn Milne is a product sales manager at Joe Johnson Equipment.

PARAMETRIC STUDY OF PULLBACK FORCES ON PIPELINES INSTALLED BY HORIZONTAL DIRECTIONAL DRILLING

By Ashkan Faghih, Anup Ghimire and Dave Dupuis

This paper reviews the design parameters for the pullback force calculation during Horizontal Directional Drilling (HDD) method. A comparison was made between actual measured pullback forces and theoretically calculated values for more than 50 HDD projects. The study showed that the measured pullback forces were higher than the theoretically calculated forces for small HDD installations, while the results were reversed in the case of medium and particularly large HDD projects. Among many factors affecting pullback force, the design values for soil coefficient of friction, fluidic drag coefficient, drilling mud density and roller coefficient of friction are often assumed the same in the calculation for all different HDD projects.

A parametric study was carried out to show the significance of these design input values in the pullback force estimation. Comparison of the results with the actual recorded pullback forces suggested modifying the design values based on the specific design case in order to enhance the accuracy of theoretical calculations. Design of Experiment (DOE) methodology was also used to further study the significance of design parameters on pullback force. The study showed that the order of significance of the design parameters varied for different case studies and the impact of one factor on pullback force is relatively independent of the level of the other factors.

INTRODUCTION

The HDD methodology has three essential stages: pilot bore, pre-ream and pullback. During the pullback stage, the pipe being installed is subjected to a complex combination of various forces. Accurate estimation of pullback force is necessary during the design stage of HDD projects to select the appropriate product pipe and rig size. The product pipe should be designed to have adequate strength to avoid damages during installation while the HDD rig should be capable of successfully pulling the pipeline.

Pullback force estimation can be relatively complicated due to the numerous factors affecting the pullback. Pipe properties, borehole geometry, existence of a buoyancy control, soil properties, drilling fluid properties, pipe handling on surface and rate of pullback are some of the many factors that are significant in pullback force estimation. Most of the required information for force analysis is site specific, vary from one job to the other and some is unknown or hard to determine. Therefore, implementing simplifications and assumptions into calculations for engineering design purposes are an inevitable fact. The key to a good design of HDD crossings is to select the right parameters for each specific project using rational assumptions, despite the many uncertainties associated with each project.

Pullback force calculation method based on the Pipeline Research Council International (PRCI) (J.D. Hair & Associates, 2008) has been widely accepted in the industry as it incorporates well-known static and dynamic concepts and applies them for use in HDD design. The total pull force required for pipe installation is calculated by summing forces resisting the pipe movement in straight and curved segments of the borehole. PRCI has proposed equations for different sections of drill path as the pipe is pulled through each of them.

Design of HDD projects is important particularly for the larger scale projects where any delay in project execution could create an economic nightmare and an efficient design could result in considerable savings while delivering the project on time. This paper presents the results of a comparison between the predicted and actual measured pullback forces for more than 50 projects. To further investigate the significance of design input variables, a parametric study was completed. Design of Experiment (DOE) was also used to study the dependency of the calculated pullback force on the design variables.

THEORETICAL VS. MEASURED PULLBACK FORCES

Fifty-four HDD projects located throughout Alberta and Northern British Columbia were selected to compare estimated theoretical pullback forces vs. actual measured forces. These projects were designed, inspected and monitored during their construction by CCI Inc. between 2012 to 2014. The projects involved installation of single steel pipe ranging in diameter from 114 mm (NPS 4) to 1,067 mm (NPS 42). The subsurface geological materials encountered during the projects comprised clay, silt, sand, gravel overburden soils and clay shale, sandstone, siltstone and coal bedrock. The HDD rigs ranged in size from 80,000 lbs (push/pull) to 110,000 lbs for small HDD installations, 140,000 lbs to 220,000 lbs for medium HDD installations, and 330,000 to 1,100,000 lbs for large HDD installations.

Actual rig load during pullback operations was recorded in the field for each project. In a majority of the cases, the maximum rig force was recorded near the pullback completion. Assuming that the forces required to pull the drill pipes and the reamer assembly are negligible at the end of the installation, the actual rig force can be compared with the theoretical force required to pull the product pipe. In general, it is a conservative approach to compare the maximum theoretical pullback force calculated based on PRCI with the actual maximum rig load. However, due to the lack of reliable data to quantify the amount of force required to pull the reamer assembly, there are currently no de-

sign methods available to estimate the actual HDD rig pull force. HDD engineers estimate the total rig load by adding safety factors to their pullback force calculations.

The theoretical and measured pullback forces for all 54projects were summarized in Figure 1, which illustrates pullback forces based on the HDD rig size used on each project. The projects were categorized into three groups: small HDD, medium HDD and large HDD installations. The average variation observed between theoretical and actual forces was different for each group. For small HDD installations, actual forces were 35 percent underestimated by the theoretical calculations while theoretical forces were higher than actual loads by 26 percent and 54 percent for medium and large HDD installations, respectively.

It should be noted that the execution of the HDD construction is a major factor affecting the pullback force. Generally speaking, better quality of workmanship, better equipment, and better execution of the job are implemented for large HDD installations to account for the higher risks and costs associated with each project. Proper conditioning of the borehole, multiple reaming passes and slow pull rate in large HDD operations eliminate excessive mechanical work required for pulling the pipeline. On the other hand, poor borehole cleaning in small HDD projects leads to additional forces required to displace soil cuttings during pullback. The over conservatism in PRCI equations is another factor that con-

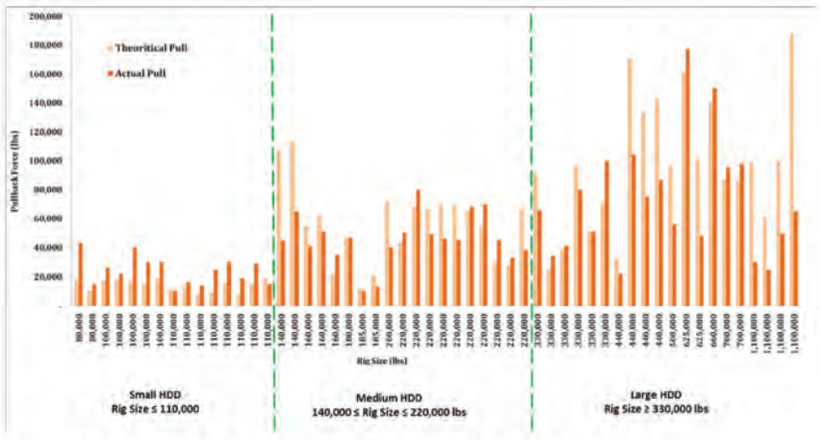

Figure 1. Comparison of theoretical vs. actual pullback forces for fifty-four HDD projects.

tributes to overestimation of pullback forces in longer and larger diameter HDD crossings.

Accuracy of pullback force estimation can be improved by modifying the design input values and safety factors. The type of project, subsurface conditions and quality of project execution can all be taken into account during the design stages of HDD operations. Careful selection of design input values are necessary in order to properly estimate the actual pullback process. The next section presents a parametric sensitivity analysis to investigate the changes of design input values on pullback force and compares the estimated forces with actual measurements.

PARAMETRIC STUDY

The HDD pullback force calculation depends on various parameters. Some of these parameters depend on site specific conditions such as borehole geometry, subsurface conditions and pipe properties, and their input values vary according to the case requirements. However, certain parameters such as soil coefficient of friction, drilling mud density, fluidic drag coefficient, and roller coefficient of friction are usually assumed the same for all the cases. In this parametric study, significance of these parameters on pullback force calculation is investigated. The sensitivity analysis was conducted for two case studies; representing small and large HDD installations. Table 1 presents the parameters of the case studies.

Typical values and ranges for the selected design parameters are discussed below:

i) Soil Coefficient of Friction, μ_{soil} - This parameter depends on the soil conditions along the bore path, which the pipeline is pulled through. PRCI suggested a value of 0.3 for HDD installations where the pipe is pulled through a hole filled with drilling fluid. For this study, a range of values from 0.2 to 0.4 is defined for this parameter.

ii) Drilling Mud Density, W_{mud} - Typically, the range for drilling mud density in HDD application varies from approximately 9 ppg (1078kg/m3) to 11 ppg (1318 kg/m3), considering clean bentonite content to higher solid content. A conservative value of 14 ppg (1678kg/m3) is used in this study as the upper limit.

HDD Parameters	Case 1 (Small HDD)	Case 2 (Large HDD)
Pipe Size	NPS 10	NPS 24
Wall Thickness (mm)	5.6	12.7
Pipeline Grade (MPa)	359	483
Radius of Curvature (m)	300	500
Depth of Crossing (m)	17	28
Length of Crossing (m)	210	1358
Buoyancy Control	No	No

Table 1. Parameters of the HDD projects

iii) Fluidic Drag Coefficient, μ_{mud} – The fluidic drag coefficient depends on the drilling fluid rheology, flow rate, annular geometry, and rate of pull. The PRCI recommends the value of 0.025 psi for the fluidic drag factor. A range of 0.0025 psi to 0.0475 psi was selected for this study. Further details on the fluidic drag coefficient can be found in Faghih et al. (2015).

iv) Roller Coefficient of Friction, μ_{roller} – The PRCI calcula-

tion does not typically consider the friction between the pipeline and the roller on the surface. Hence, a range of 0.0 to 0.2 was selected for this parameter.

Pullback force was calculated as each parameter deviated from its mean value. The mean values of the parameters are μsoil=0.3, Wmud=1400 kg/m3, μmud=0.025 psi and μroller=0.1. These values are commonly used by engineers to design HDD projects.

Figures 2 and 3 show the results of the sensitivity analysis for small HDD and large HDD installations, respectively. Ranges of actual rig loads recorded near the pullback completion are also shown on the graphs. The pullback estimation based on the average values of the parameters suggested maximum pullback forces of 17,000 lbs for case 1 and 246,000 lbs for case 2. These graphs show the ranges of design input values that bring the pullback force estimation in the actual load zone. For the case of small HDD as shown in Figure 2, higher values of the defined range for mud density, soil coefficient of friction and fluidic drag coefficient would result in realistic pullback force estimation. For large HDD as shown in Figure 3, lower range of μmud and μsoil would lead to better accuracy in pullback force estimation. In both cases, changes in μmud resulted in higher amount of variation in pullback force. This is due the wide range of possible input values for this parameter. Roller coefficient of friction had the least impact on pullback force for both case studies.

DESIGN OF EXPERIMENT

DOE is a systematic approach to the investigation of a system or process, where the planned changes are made to the input parameters to identify their effects upon the response or the output. The parameters of interest are first identified, and then the experiment or analysis is carried out at certain ranges of the value, known as 'high' and 'low' representing the maximum and minimum magnitudes of the parameters. DOE results can be used to understand the effect of each parameter and their interaction (if any) with other parameters upon the output.

'One change at a time' testing always carries the risk that the experimenter may find one input variable to have a significant effect on the response (output) while failing to discover that changing another variable may alter the effect of the first (i.e. interaction between parameters). This is because the temptation is to stop the test when this first significant effect has been found. However, DOE plans for all possible dependencies in the first place, and then prescribes exactly what data are needed to assess them, whether input variables change the response on their own, when combined, or not at all.

For the case study described in this paper, the identified parameters were

set at two different levels (low and high) and then the pullback force was calculated. 2^k combinations were considered that represents the 'full factorial' design where 2 represents the level of ranges, which is 'low' and 'high', and ^{k} represents the number of parameters chosen which is 4 in this study. So, a total of 16 runs of pullback force calculations were measured at different combinations of defined parameters at different levels. The parameters and their ranges are presented in Table 2.

Table 3 shows different combinations used in the analysis where "-" refers to the low range of the parameter while "+" represents the high range. The effects of terms A, B, C and D on the response are called main (single) effect and different combinations of the main factors such as AB, AC, …, ABCD are called interactions of factors.

Design-Expert software (Design-Expert, 2015) was used to carry out the parametric study. Different geom-

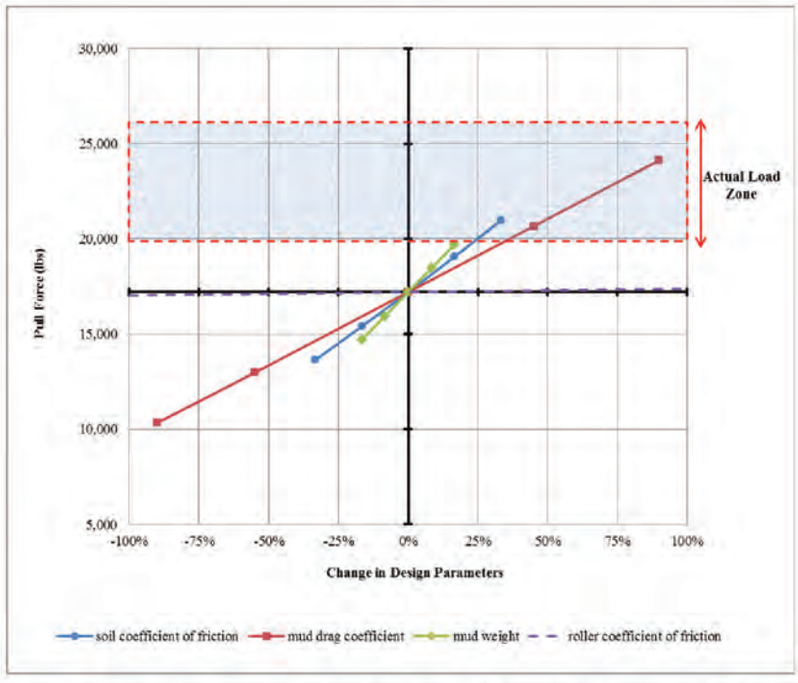

Figure 2. Sensitivity analysis on pullback force and the actual load zone for case 1, small HDD.

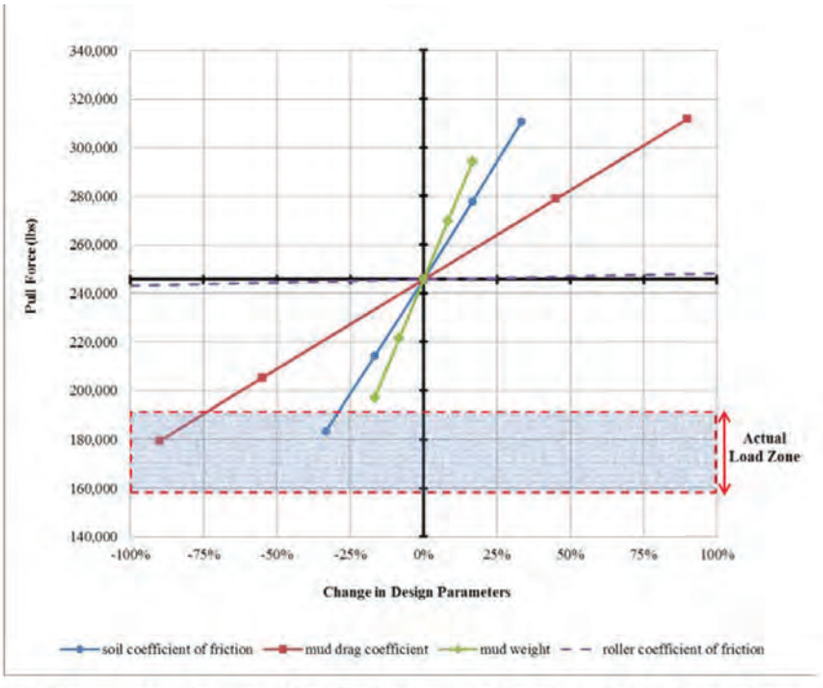

Figure 3. Sensitivity analysis on pullback force and the actual load zone for case 2, large HDD.

etries, pipe sizes, and drill lengths were tested in the analysis for small, medium and large HDDs to represent all possible design scenarios. The pullback force was calculated for different combinations of these parameters (as shown in Table 3) for each case. Then, the results were analyzed using the factorial analysis and Analysis of Variance (ANOVA). Table 4 summarizes the significance of the parameters for different HDD cases.

The analysis showed that the main effects of factors A, B and C were more significant than the interaction of the parameters as shown in Table 4. It simply means that the impact of the parameters on pullback force is relatively independent of the level of the other factors. Fluidic drag coefficient (parameter C) had the highest impact on pullback force for small and medium HDD while drilling mud density (parameter B) had the highest contribution for large HDD. Therefore, the order of significance

Parameters	DOE Notation	Low (-)	High (+)
Soil Coefficient of Friction - μ_{soi}	A	0.2	0.4
Drilling Mud Density (ppg) - W_{mud}	B	9	14
Fluid Drag Coefficient (psi) - μ_{mud}	C	0.0025	0.0475
Roller Coefficient of Friction - μ_{roller}	D	0.0	0.2

Table 2. Ranges of the parameters

of design parameters varied for different case studies

Table 4 also shows that there is a small interaction between factors A and B. In the analysis for the medium HDD installation, the pullback force was increased by 78 percent when the soil coefficient of friction changed from 0.2 to 0.4 while drilling mud density was set at high value. By setting the mud density at low value, 55 percent increase in pullback force was resulted by changing the values of soil coefficient of friction from low to high. The same agreement was obtained for small and large HDD installations.

It is also can be seen from Table 4 that the effect of roller coefficient of friction (parameter D) was negligible on pullback force. Table 4 also shows that the percentage for contribution of curvature is very low indicating that the relationship between the pullback force and the parameters are linear.

CONCLUSIONS

Accurate pullback force estimation is complicated due to the existence of many factors, which some are site specific and some are unknown or hard to determine. Therefore, implementing simplifications and assumptions into calculations are necessary for engineering design purposes. As a result, design practice recommended by PRCI is widely used in the industry. However, there is a wide range of acceptable design inputs that can be used in the pullback force calcula-

Combinations	A	B	C	D
1	-	-	-	-
a	+	-	-	-
b	-	+	-	-
ab	+	+	-	-
c ac	-	-	+	-
bc	+	-	+	-
abc	-	+	+	-
d	+	+	+	-
ad	-	-	-	+
bd	+	-	-	+
abd	-	+	-	+
cd	+	+	-	+
acd	-	-	+	+
bcd	+	-	+	+
abcd	-	+	+	+
	+	+	+	+

Table 3. Matrix of the parameters

tions. In practice, the design values of parameters such as of μsoil, μmud, Wmud, and μroller are often kept the same regardless of the project types. Comparisons between measured and predicted pullback forces proved that larger pipe installation in longer crossings may require less pullback force in practice compared to the one calculated theoretically. Reverse statement is valid for the case of small pipes and shorter crossings. Other factors such as proper borehole cleaning, quality of work execution, and pullback rate are among the many parameters that can change the amount of pullback force during pipeline installation.

A parametric study showed how pullback force changes as values of design inputs vary. For the case of small HDD installations, higher range of values for μsoil, μmud, and Wmud led to close estimation of actual loads. The study for large HDD installations suggested using the low values of μmud and μsoil for design purposes. Further analysis by DOE proved that main (single) effect of factors is major in pullback force while impact of one factor on pullback force is relatively independent of the level of the other factors.

Coded Parameters	% of Contribution to Pullback force		
	Small HDD	Medium HDD	Large HDD
A	8.55	30.87	38.27
B	15.18	31	43.83
C	71.8	33.7	11.76
D	0.88	0.1	0.11
AB	2.33	4.24	5.93
Curvature	0.032	0.003	0.002

Table 4. Summary of effects of main factors and interaction of factors

Ashkan Faghih, and Anup Ghimire are with CCI Inc. Edmonton, Alberta, Canada and Dave Dupuis is with CCI Inc., Calgary, Alberta, Canada.

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American Augers

When one of American Augers best customers wants the best, we deliver. Karl Quackenbush of Mears Group wanted the cleaning capacity of the American Augers' largest system, the MCR-10000 with the addition of the best shakers in the industry – Derrick. Answering the call, American Augers designed and created the best cleaner in the industry, the MCD-1000 featuring Derrick FLC-500 linear motion shakers with patented Pyramid Screen technology. The three-tank system has up to 1,000 gpm of cleaning capacity and a centrifugal mud pump all incorporated in a rock-over design on a tri-axle suspension. This high volume reclaimer reduces volume of solids by controlling the overall moisture content which leads to easier fluid disposal. As with all American Augers products, we take pride in the support we provide to our customers around the world, 24 hours a day, 365 days a year.

Armadrillco

Armadrillco offers the most secure transmitter housing to date. Never lose a transmitter downhole again, while using our proven patented technology. Vibration-proof lock pins are used to secure the door . Our lock pins will not vibrate loose like bolts. Your men cannot over torque and break them. Versatile box to box transmitter housings. Perfect for all of your drilling needs including air hammer and mud motor operations. With a single 1-in. hole or dual 5/8-in. holes, these housings provide greater flow than multiple small hole designs. High Flow Sealed Side Load TRANSMITTER HOUSING. Cradling your transmitter in urethane your transmitter is protected from debris, heat and vibration. It also is one of the highest flow housings on the market, if not the highest. With an ingenious sealed port, wired transmitters will fill right at home. Visit armadrillco.com to investigate further.

Atlas Copco

The new Atlas Copco Secoroc 12 ¼-in. Klaw hole opener gives horizontal directional drillers an aggressive reaming tool for softer formations. A one-piece 4140 alloy steel bit body provides complete blade and body strength. Stabilizer pads center the hole opener in the pilot bore, and 3D-designed cutter locations and bit features are CNC machined to meet exact design specifications and ensure product repeatability. The Atlas Copco Secoroc Klaw hole opener provides higher penetration rates, efficient cleaning of bore, smoother drilling and longer lasting bits. Its 19-mm carbide pick cutters are easily replaced when worn. Stabilizer pads on the bit body center the hole opener in the pilot bore. Flushing is provided by six nozzles available in sizes 8 to 12 in. The Klaw hole opener's aggressive plowing action enables higher penetration rates, more efficient cleaning of the bore and smoother drilling with longer bit life.

Bit Brokers International

Bit Brokers International is proud to introduce the VersaReam 2.0. The VersaReam is a patent-pending PDC reamer that provides Versatility to the drilling industry by allowing drillers to change the size of their reamer by simply changing the blades. The VersaReam is changing the drilling industry as we know it. Not only does it bring Versatility to the driller by being able to change the size of the reamer, but it also drills up to three times faster than traditional roller cone reamers in the right formations. The VersaReam is also bi-directional, which allows HDD drillers to either push or pull ream without breaking it off the drill string. The bi-directional design also produces a much cleaner hole which allows it to be either pushed or pulled back after the ream is finished with nearly no effort by the drill rig.

Brand X Drilling Tools

Manufacturer-direct, high-quality, American-made PDC bits at prices at or below the price of imported or rebuilt PDC bits. Higher grade diamond cutters. Thicker diamond cutters. HDD appropriate jet nozzle sizes. HDD appropriate thread connection sizes. Available in all popular sizes used in the HDD industry (in inches): 4.75, 5.5, 6.25, 6.5, 8.5, 9.875, 10.625 and more. High grade steel bodies. 3, 4, 5, 6 and 7 blades. In Stock for immediate shipment. We manufacture PDC hole openers, as well. For more information email *brandxdrillingtools@gmail.com* or visit: *facebook.com/DrillBrandX*.

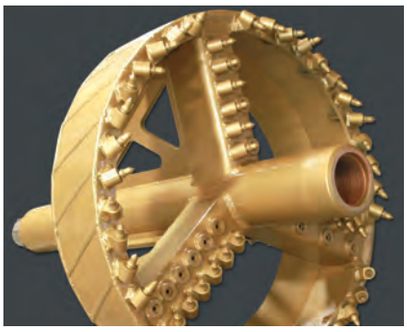
CCI Rentals

With decades of experience, CCI Rentals newest release, the Pipe 360 Cradle, has combined safety with versatility. CCI Rentals new Pipe 360 Cradle is a fully self-contained pipe lifting device that demonstrates innovation in day-to-day pipeline operations. The Pipe 360 Cradle is perfectly suited for all types of pipe handling scenarios. It works with pipe sizes from 20 to 48 in. It is also great for tackling large HDD pullback operations. The Pipe 360 Cradles are specially designed and optimized for handling line pipe. These cradles can be used with concrete, steel, plastic, and cast iron pipe across the full range of coatings such as tape, fusion bonded epoxy, concrete, and various insulations.

Century Products

Century's exclusive product lines offer tools suitable for a diverse range of drilling rigs and formations to be encountered. In line with Century's reputable Hole Openers are Century's Fly Cutters. Ideal for soft sand and clay formations, as well as harder gravel and cobble formations, Century's Fly Cutters are engineered for maximum performance and reliability. Built for both the large and small rig class, Century's Fly Cutters are available in Standard Duty (SD) and Heavy Duty (HD) Series for rigs more than 200,000 lbs., and Light Duty (LD) Series for rigs 50,000 to 200,000 lbs. Every Fly Cutter utilizes a hardened shaft welded to spokes for superior strength. Replaceable Carbide Jets are strategically placed both forward and aft to clear cuttings. A hard-

faced ring with welded replaceable carbide teeth incorporates full concentric radial tooth coverage for high penetration rates. Century's Fly Cutters are available in custom one-of-a-kind designs or industry leading off-the-shelf solutions.



CETCO

Maintaining borehole integrity demands a drilling fluid you can count on for all drilling conditions: It demands HYDRAUL-EZ from CETCO. HYDRAUL-EZ is a specially formulated bentonite drilling fluid that offers superior suspension properties and borehole stability for all soil conditions. To see the light at the end of the borehole, choose HYDRAUL-EZ – the product of choice among experienced drillers. Our complete line of professional drilling products will keep your operations running at peak efficiency and will enhance the cost-effectiveness of your drilling operations. The experienced team of field engineers and research scientists at CETCO offer drillers on-site mud schools, advanced technical support, and continuous product development. Excellent service and support is a priority at CETCO. Check out our complete line of professional drilling products and other useful tools such as our HDD Calculator on our website at cetco.com/dpg.

Copperhead Industries

No matter how difficult or how long the HDD project, Copperhead Industries now has the widest breadth of tracer wire manufactured with drillers in mind. SoloShot EHS is six times the strength of comparable sizes of solid copper wire. SoloShot EHS incorporates an HDPE coating thickness of 45 mil to protect the wire. SoloShot Xtreme is the toughest, most durable tracer wire designed for the most critical HDD bores. With a break load of 4,700 lbs, it is greater than all other tracer wires. SoloShot Xtreme has a 50-mil HDPE coating thickness for additional protection. All SoloShot HDD tracer wires manufactured by Copperhead Industries have a patented process for HDD and are manufactured with the proven copper clad steel technology. Both SoloShot EHS and SoloShot Xtreme can be incorporated with the Copperhead complete tracer wire system utilizing test stations, connectors and grounding anodes. Visit *copperheadwire.com*.

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To improve jobsite efficiency and reduce jobsite expense, the new Ditch Witch MR90 mud-recycling system promises versatility on the job. The single, self-contained unit can mix and recycle mud, handle spoils, and is the only unit that can be transported full of fluid. Powered by a 25-hp Kubuta Tier 4 engine, this compact unit is designed for small to medium-size drills (pullback ratings from 20,000 to 60,000 lbs) with up to 90-gpm cleaning capability. The MR90 uses hydraulic leveling on shaker assembly and trailer jackstand, delivering fast setup – as few as 10 minutes. Learn more here: ditchwitch.com/trenchless/fluid-management/mr90-mud-recycler.

Drillhead Inc.

Starting at only $375, the Rok-Klaw from Drillhead, Inc. is an economical, yet very rugged tool for drilling through medium-hard soil, soft rock and cobble conditions. The teeth can be quickly replaced without removing the bit from the housing. Sizes range from 3 to 6 ½ in., they are available in all Vermeer and Ditch Witch bolt patterns. Its proprietary design uses standard size "trencher" teeth available from most HDD supply stores. Contact Drillhead Inc. at 580-222-4851 or visit *drillhead.net*.

E&M Supply

We have the 5 ½ in. FH DOUBLE SHOULDER— the single most popular drill stem for maxi rigs between 300,000 – 750,000 lbs. E&M SUPPLY GROUP has a large supply of this pipe available for sale at our Breaux Bridge, La. facility. This pipe is hard to come by. The majority of premium 5 ½-in. that comes into the market is standard FH, not double shoulder. HDD operators prefer double shoulder because it offers more torsional strength than standard FH, and because it is more resistant to over-torque. If your rig has at least 50,000 ft-lbs of rotary, then 5 ½-in. double shoulder is the way to go. Please call us at 337-332-0239 or email *brandon@emspecialty.com* for more info on this drill pipe. E&M SUPPLY GROUP has been the industry leader in premium used drill pipe for nearly three decades. We carry all sizes HDD drill pipe, along with experienced product support and service after the sale.

Ezebreak

Ezebreak's Micro-Blaster rock and concrete breaking systems allow users to tackle small to medium demolition projects in almost any location including inside buildings and confined spaces. The active component used by the Micro-Blaster System is a proprietary cartridge design containing a small quantity of propellant which when initiated provides sufficient gas pressure to crack hard materials. Our systems require only a 5/16-in. (8-mm) diameter drilled holes, 10 to 16 t deep, for quick and effective demolition. The dangers of collateral damage from shock waves or fly-rock are essentially eliminated and no Federal Blasting Licenses are required for legal use. Used by miners, HDD contractors, rescue personnel, prospectors, excavators, cave explorers, and farmers to quickly solve difficult demolition problems.

HammerHead Trenchless Equipment

HammerHead Trenchless Equipment has introduced the HammerHead ROUGHNECK R600, the largest of its pneumatic percussion drilling systems for use in HDD applications. Designed for drilling solid rock with bit diameters of 7.25 to 8 in., the R600 gives HDD contractors the ability to complete larger diameter bores in fewer passes as well as access to a wider range of single-pass boring applications. The larger bits driven by an R600 also increase the range of single-pass applications the driller has access to such as in communications and or other service installations. The R600 completes the range of existing HammerHead ROUGHNECK rock drills available to HDD customers. It joins the R400 designed for 5.25-in. straight and offset bits and the ROUGHNECK R500 for straight and offset bits to 6.25 in. in diameter. All three ROUGHNECK hammers turn any horizontal directional drill in the construction industry into a high-production rock drilling machine. Capable of penetration rates of 150 ft or more an hour, the rock hammers feature heavy-duty, high-flow housing; patent-pending pullback kit; control station/oiler; and drill conversion kit.

HDDJetNozzle.com

HDDJetNozzle.com has introduced a new line of high pressure Jet Nozzle Assemblies for the HDD, Oil and Gas, and Well Servicing industries. These assemblies are highly adaptable and designed to be incorporated into a wide range of in-hole tools, while being designed for maximum performance and durability. These Jet Nozzle assemblies are a central part of building in-hole tools, e.g. hole-openers, fly-cutters, barrel reamer's, hole cleaning swabs, jet bits, Oil Well servicing, cleaning and fracking tools etc. In addition to our popular Series 65 nozzle assemblies, HDD Jet Nozzle has recently introduced the new Series 45 high pressure tungsten carbide nozzle for applications requiring a smaller, more compact nozzle size, e.g. HDD utility market, as well as high pressure well servicing tools. The Series 45 also offers smaller orifices to accommodate HDD rigs having smaller pumping units. Visit us at *HDDjetnozzle.com*.

Herrenknecht

Herrenknecht has collaborated with recognized HDD specialists to develop innovative downhole tools. With these, crossings can be carried out more quickly and economically. With the new Full Face Hole Opener, pilot holes can be enlarged in a single step. The tool is modular in design. Thanks to replaceable disc cutters it can be used in various ground conditions and quickly and economically refurbished or modified. They also recently developed Down Hole Jet Pump ideally complements it. The pump is installed directly behind the Full Face Hole Opener, cleans the borehole and removes the cuttings directly inside the drill string. As a result, the simplest drilling fluid can be used even with larger cuttings. Its only function remains the support and sealing of the borehole. With the combination of Hole Opener and Jet Pump an exactly round, clean borehole is created in one single step and expensive bentonite can be saved.

Hunting Trenchless

With a design that sets them apart from conventional mud motors, the new Hunting M-Series Mud Motors incorporates SWB (Survey While Boring) Technology that directly improves your ability to control the bit's direction by locating the sonde housing into the bearing housing just three feet behind the bit. This provides the operator more accurate tracking information than any other mud motor in the industry. And with Hunting, our mud motors come with a unique sealed oil bath bearing design eliminating the problem of mud flushing through the system. Call (855) 367-9296 for more information or visit *huntingtrenchless.com*.

INROCK

INROCK has introduced a new tool specifically designed for HDD crossings. INROCK's ABIA mud motors provide contractors bit inclination in real-time by taking critical steering readings directly behind the bit. Traditional wireline steering technology measures 30 to 40 ft behind the bit, often times too late to make critical decisions. This information is essential on tight radius bores, large diameter pipe, or when the chance of deflections is high, for instance, when drilling through fractured formations. Having this information available in real-time can make the difference between keeping the bore on target and having to abandon the hole. For more information, email *sales@inrock.com* or visit *inrock.com*.

Jet-Lube

ECO-SAFE Drilling Compound provides excellent protection against seizing and galling and can be used for pipe joints or thread connections. ECO-SAFE is an entirely metal-free compound containing carbon-based fibers and additives and other extreme pressure and anti-wear additives. These are blended into JET-LUBE's complex base grease. This new base grease offers the additional advantage of superior adhesion to wet steel surfaces and resistance to water wash-off.

KEMTRON Technologies

KEMTRON Technologies has become a leading manufacturer of effective mud recycling systems in North America. Designed for today's HDD drilling contractor with 80,000 to 150,000 lb pullback rigs in the trenchless, water-well or geothermal industry; capable of processing up to 600 gpm of drilling fluid. Featuring an industry-first touch screen control panel with Wi-Fi capabilities, the Tango 600HD2 allows the operator to run the system from a smart phone, tablet or laptop. In addition, the Tango 600HD2 features the new Hyper-G six-panel linear motion shaker and single-point leveling jack, Firestone single-piece vibration isolation system, independent centrifugal pump pockets for direct maintenance access and eight 4-in. desilter hydrocyclone manifold. Trailer-mounted systems feature a heavy-duty dual-axel configuration with hydraulic leveling jacks for efficient unit placement at

rig site. The Tango 600HD2 tank has been significantly increased from 3,000 gals to an impressive 4,000-gal capacity with new fold out/walk up ladder and increased working deck space.

M-I SWACO

M-I SWACO, a Schlumberger company, offers Drilplex HDD inorganic viscosifier, specially engineered for water-base bentonite drilling fluids to accommodate both maxi, as well as compact HDD rigs. The viscosifier improves solids suspension, enables a higher rate of penetration, optimizes cuttings transport, and creates borehole stability, thereby lowering drilling costs. Drilplex HDD viscosifier allows the formulation of fluids with shear-thinning properties, resulting in a drilling fluid with both dynamic and static carrying capabilities that does not shear degrade at a high shear rate. When mud is not circulating, it instantly reverts to a gelled state, resulting in a high suspending capacity indicated by high, non-progressive but fragile gel strength readings. For more information, visit *miswaco.com/hddmw*.

McLaughlin Mfg.

The Vermeer VX 50-500 vacuum excavator by McLaughlin features Tier 4 Final engine technology and a new engine enclosure to help reduce engine noise levels and vibration. Operator-friendly enhancements include a large access door to the engine enclosure to provide improved accessibility. The unit's three-stage cyclonic filtration system allows for wet and dry vacuum excavation while prolonging filter life and keeping maintenance costs low. An improved external hydraulic door opens at an 85-degree angle, allowing for easier and more rapid dumping and cleaning of the spoils tank. A patented mechanical cam-over locking system provides a 360-degree positive door seal, even under reverse pressure, without additional clamping requirements. The VX 50-500 vacuum excavator also features a low profile design, allowing access to areas previously limited by height restrictions. For more information visit *mclaughlinunderground.com* or email McLaughlin at *mmole@mightymole.com*.

Melfred Borzall

A small, mud-filled pit is the last place you want to be fighting to change out a drill head after a pilot bore. With Melfred Borzall's new (patent pending) Eagle Eye FastBack you don't have to. With just a hex wrench you can be pulling back product within minutes of completing the pilot bore. The Eagle Eye connects to the Eagle Claw hard soil bit, allowing you to pullback without ever having to take the drill head off. Rear facing carbides and MudBoost fluid ports make sure your pullback is fast and successful. This economical, compact reamer is perfect for jobs with limited space. To learn more, call 800-833-1252 or visit *melfredborzall.com*.

Pioneer One

Pioneer One (P1) the HDD steerable air hammer leader has added another rock tool to its arsenal. P1 coupled an air motor with its hammer attached to the bit box. This combination will allow a HDD contractor to go past 2000 ft in rock. The ROP (rate of penetration) is up to 55 percent faster than a mud motor with tricone bit even in extreme hard rock. Additional benefits are the use of aerated fluids and environmentally friendly oil, in situations where normal drilling fluids are not appropriate. The air motor/hammer with the use of aerated fluids is the ideal tool when you have extremely porous sub-normally pressured and cavernous formations or just hard rock. There's no need for large recyclers and/or auxillary mud pumps while building the pilot hole. The air motor/hammer is for wireline only at this time.

Premier Drill Pipe Ltd.

Premier Drill Pipe LTD manufactures and distributes the most complete line of horizontal drilling (HDD) tubulars in the world. We set the standard for forged-end inertia-welded rods and have yet to have a single inertia weld failure. Premier is so confident in our inertia-weld that we offer an unconditional guarantee on the weld irrespective of operating conditions. Premier provides virtually all sizes of Vermeer, Jet Trac and Case compatible rods, as well as rods for other rigs. We also design and manufacture specialty strings for any number of unique projects. HDD projects can be unpredictable and the need for drill rods may be immediate, that is why Premier maintains a qualified network of distributors and stock points in Houston, Los Angeles, Atlanta and Minneapolis. Our experienced staff and advanced manufacturing technology is the basis for our superior product quality.

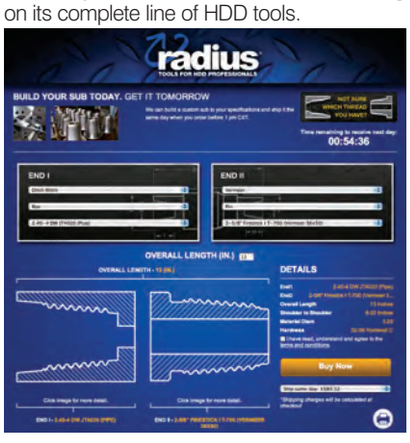
Prime Horizontal

The Prime Horizontal MudVis System is an automated system that measures and logs the Viscosity and Specific Gravity of your drilling fluids. Designed specifically for the HDD industry, MudVis continually samples your stock or mixing tank bentonite at regular intervals. The Viscosity and Specific Gravity values are stored internally and are displayed on a sunlight viewable LCD screen for easy viewing at a glance. With the unit's enhanced wireless capabilities it is possible to monitor live fluid

data from around the drill site using a wireless display, laptop or standard mobile device. It also allows for wireless downloading of stored data. MudVis enables you to react quickly to changing fluid characteristics, reducing your operational risk. It saves time for your onsite personnel improving their efficiency and allows detailed post project analyses using the recorded data. MudVis requires minimal setup and maintenance as it is self-calibrating and self-spooling.

Radius Tools

Contractors continue to count on Radius Tools as their "Go to" source for all HDD tooling. In an effort to support their customers, Radius continues to expand its "HDD Custom Sub Service." Contractors can still log on to radiushdd.com and design virtually any connection they require and how fast they need it. Now Radius has expanded its capacity in order to offer even faster service. For critical situations where rigs are down or jobs are on hold, Radius offers Custom subs — made and shipped the same day. Radius keeps a massive inventory of common cross-over and connection subs, but even if you need an odd connection rest assured, Radius can deliver. Call today for more information and a catalog on its complete line of HDD tools.



Railhead Underground Products LLC

We've made a good thing even better. The success of the 8-, 12- and 16-in. EXTReam has led us to the 6- and 10-in. EXTReam reamers. Now available in five sizes from 6- to 16 in. in diameter. Connections for virtually every drill. The newly designed 6-, 8- and 10-in. EXTReam Reamers are built with an API pin and box with a removable pulling eye at the back of the reamer. This allows the user to quickly hook up many configurations. For more information, 817-594-6663 or visit *railhead.com*.

RIDGID

The RIDGID SeekTech SR-24 Line Locator streamlines the creation of accurate maps of underground utilities in order to protect critical assets. Using integrated Bluetooth communications, it transmits locating data to a third-party survey grade GPS or a mobile device. Data logging capabilities allow recording GPS and locating data to an onboard micro SD card. In addition to OmniSeek passive locating capabilities, the SR-24 can be programmed to detect any active frequency from 10 Hz-35 kHz. The free RIDGIDtrax app, for use on iPhone, iPad or Android, provides basic utility mapping. With the SR-24, the app will display GPS position and depth of the target utility on a real-time map. A user can identify the type of utility (water, gas electric, etc.) and display multiple utilities on the same map. A completed map can be saved and viewed inside the app or exported to a universal file format for use with popular GIS programs such as Google Earth.

Sharewell HDD

Precise Drilling Components and Sharewell HDD are pleased to announce the newest innovation in reaming technology for the small and mid-sized rig market. Utilizing "Pro-Cut" cutter modelling software and the highest standard of American carbide, PDC has developed this unique self-centralizing reamer capable of outperforming the competition in a variety of formations. The HydraMax's simple yet rugged body design allows for both push and pull reaming operations and easy refurbishing for increased cost savings. Benefits: bi-directional cutting capability; reduced torque self-centralizing design; better penetration rates in all formations; capable of handling rock and cobble; easily repairable to new standard; and available in sizes from 10 to 24 in.

StraightLine HDD

The Crusher is the latest in a series of customer-generated reamer designs from StraightLine HDD. In this case, conventional thinking in rock formations dictate a hole opener for back-reaming. But a growing number of today's HDD contracts call for small-diameter bores, which eliminate hole openers as a viable option. The Crusher fills the gap. A one-piece body and shaft design, the Crusher can be configured with short-bodied radius carbide buttons for hard rock up to 25,000 psi or chisel-top carbide buttons for softer formations. Carbide buttons are located on independent cutting paths to insure maximum contact. Replaceable fluid ports deliver fluids exactly where needed to insure smooth and efficient cutting action. A tapered solid-body, which transitions into full diameter in the back of the tool, promotes stabilization in the hole and superior cuttings control. Available in diameters from 4 to 10 in., the Crusher thrives in harsh conditions, such as hardpan, cobble and solid rock.

The Toro Co.

When productivity counts, the new Toro DD4045 horizontal directional drill delivers. Combining 40,000 lbs of best-in-class thrust and pullback, along with 4,500 ft-lbs of rotational torque and drilling fluid pump infinitely variable up to 70 gpm, the DD4045 has what it takes to perform a variety of different bores. Operators will appreciate the flexibility to use either single or dual joystick

controls while drilling, the large multi-function LCD display, and the clear visibility of the tool joint that comes from having open-top vice wrenches. The DD4045 comes equipped with 52 pieces of 10-ft, one-piece-forged pipe for durability in a variety of conditions, and an easily removable pipe rack for bores longer than 520 ft. This unit boasts a powerful 160-hp Cummins QSB4.5 diesel engine, and an optional enclosed operator cabin. Please contact Global Machinery (*GlobalMachinery.com*) for more information or to schedule your next demo.

Torquato Drilling Accessories Inc.

Torquato Drilling Accessories Inc. of Old Forge, Pa., designs and manufactures a wide range of high speed Silver Bullet PDC Bits and Reamers for horizontal directional drilling. Silver Bullet PDC Bits drill 5-1/2- and 6-1/2-in. pilot holes considerably faster than roller cone bits in consolidated rock such as sandstone, limestone and shale. Our HDD PDC Reamers are available in sizes up to 26 in. in diameter for smooth and efficient reaming. Contact us today for more information at (800) 500-2487.

TT Technologies

The compact Grundodrill 4X is designed for residential service, small diameter water main installations, last mile operations, and gas pipeline applications, offering 9,800 lbs. of thrust and pullback. Using the compact drill is less intrusive and ideal for areas where larger units are not an option. The drill features a dual hydrostatic pump system and a four-auger stake down system that provides greater stability. The Grundodrill 4X also comes with the exclusive Smart Vice system that performs vice cycling operations automatically.

TuffRod

TuffRod offers the most comprehensive lineup of one-piece forged drill pipe in the United States. Forged drill pipe is available for virtually every Vermeer and Ditch Witch drill on the market, as well as several other manufacturers' drills. TuffRod drill pipe is made from only the finest quality materials. Every joint of pipe produced is subject to rigorous quality assurance procedures, which begin at the point of material selection and continue through final inspection. Processes such as upsetting, machining, heat treating are inspected and recorded by certified operators. These measures ensure that customers receive only the best quality drill pipe. TuffRod also offers both new and premium used range 2 drill pipe for maxi drills. We also provide engineering services and can design custom pipe or connections for any application. For more information call TuffRod at 844-586-9354 or visit *tuffrod.com*.

Underground Tools Inc.

Other than our swivels, the only thing spinning will be your head when you realize how strong and affordable UTI's HDD Pullback Swivels are. Several unique design features incorporated in our swivels combine to make them the strongest on the market. Four bearings and a larger shaft constructed from tool steel provide added strength you won't find with competitors swivels. Full diameter shouldered pins, recessed into the smooth and durable outer casing creates a tremendously strong connection and also allows for snag free pullbacks. These swivels also have side-mounted, recessed grease fittings which protect the fittings and also make for easy access when performing swivel maintenance. UTI offers a complete lineup of premium quality clevis x clevis swivels ranging from 8,500- to 120,000-lb working loads. Higher rated swivels with API box x clevis connections are also available. For more information call UTI 866-488-3478.

Vermeer Mfg.

The new D20x22 S3 Navigator HDD is a small footprint machine yet one that is able to increase productivity when working in urban or tight jobsites. A 74-hp, Deutz engine powers the machine and is capable of 12 percent greater power compared to its predecessor, the D16x20 Series II. The D20x22 S3 features 19,550 lbs of thrust/pullback with 2,250 ft-lb of torque. The D20x22 S3 has a faster carriage speed, which can lead to an increase in the amount of product installed per minute. The 167 ft per minute now exceeds competitive models in the same class. The D20x22 S3 features the common control system currently used on larger Vermeer drills. The system features a digital display and improved onboard diagnostics, which allow operators to customize the available drill information. The noise level output from the drill has been reduced to enhance operator comfort.

Vivax-Metrotech

As more utilities are being buried underground the importance of accurate locates is more significant than ever. The vLocPro2 series of buried utility locators from Vivax-Metrotech is the right tool to execute locates with speed, accuracy and confidence. With a range of frequencies low enough for telecom and power, and high enough for gas and water the vLocPro2 series gives you one tool for various applications. The bold left/right direction arrows will increase the speed at which you can locate and our SD and CM features will allow you to pinpoint your target line in congested areas. Our vLocPro2 is lightweight and balanced and uses rechargeable or alkaline batteries. Please visit us on the web at vivax-metrotech.com or give us a call so we can schedule a no obligation in field demonstration. (800) 446-3392.

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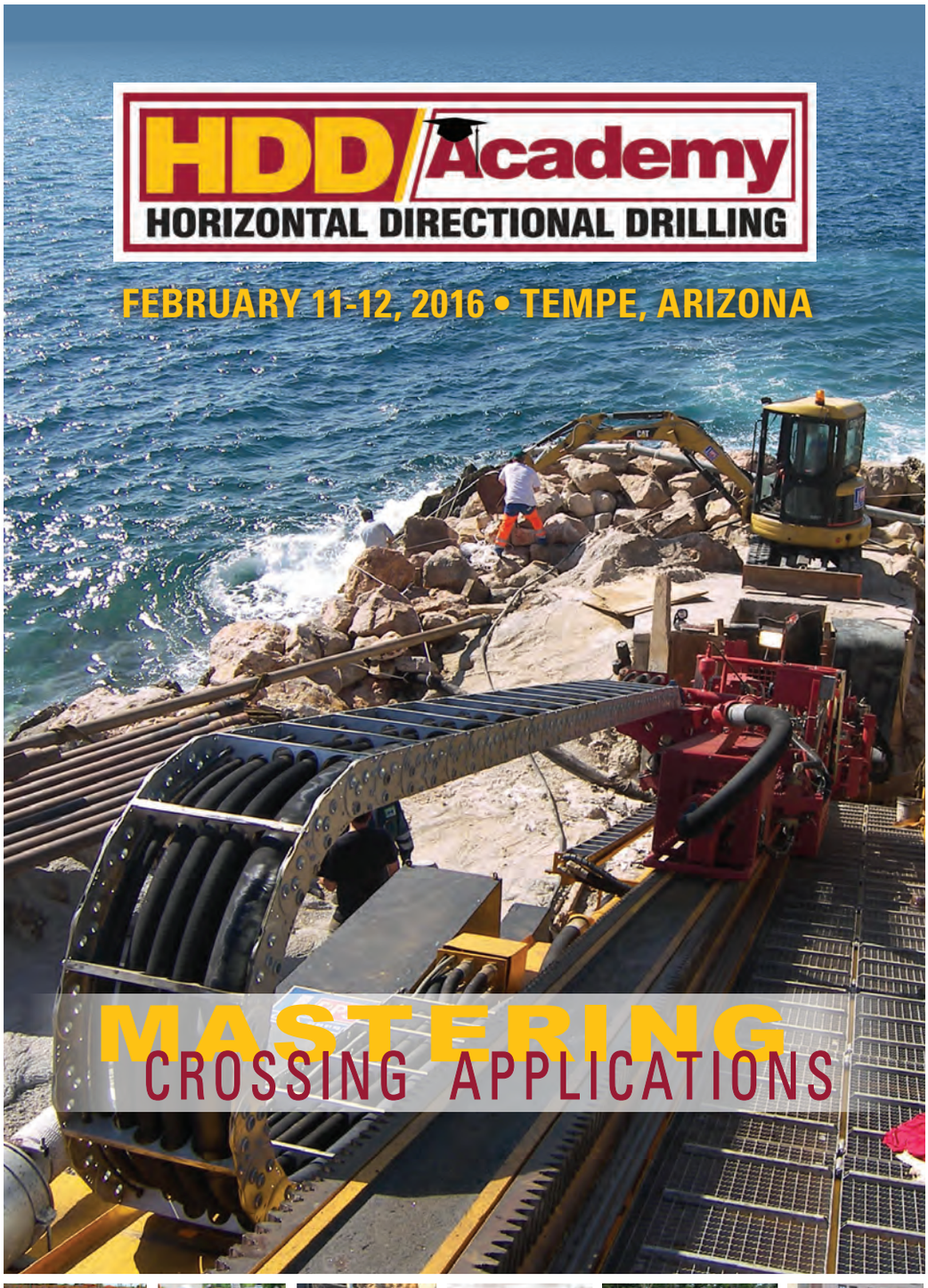

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- Environmental Considerations of Drilling Fluids
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