DEEP HOLE DRILLER

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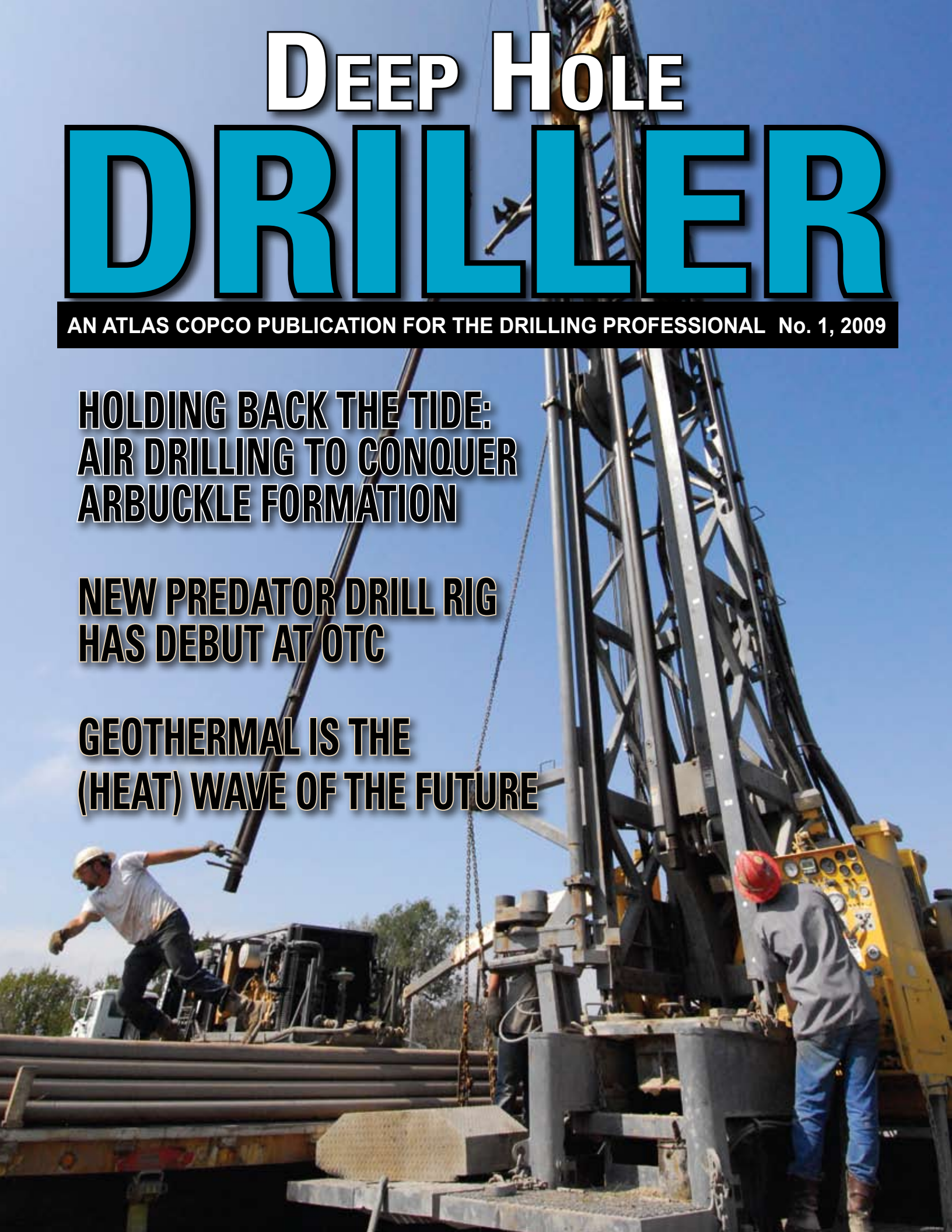

HOLDING BACK THE TIDE: AIR DRILLING TO CONQUER ARBUCKLE FORMATION

NEW PREDATOR DRILL RIG HAS DEBUT AT OTC

GEOTHERMAL IS THE (HEAT) WAVE OF THE FUTURE

FEATURED

Vol. 1, 2009

DEEP HOLE DRILLER

is published by Atlas Copco Drilling Solutions LLC. The magazine focuses on the company's expertise, products and methods used for deep hole drilling and the advancement of the industry worldwide.

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ATLAS COPCO DESIGNS NEW RIG FOR OIL & GAS INDUSTRY

EDITORIAL

By Ron Buell
Business Development Manager,
Atlas Copco Drilling Solutions LLC

Atlascopcooilandgas.com has been showing a series of animations featuring the Predator™ Drilling System, a new oil and gas product from Atlas Copco Drilling Solutions. If you haven't seen them, please take some time to sign on and have a look. Additionally, I would also like to extend an invitation to join us for Predator's introduction on May 4–7, 2009, at the Offshore Technology Conference (OTC) in Houston. Predator will be on display at outdoor booth 7311. If you plan to be at OTC, please stop by our display and take a look at the next generation of oil and gas drilling systems.

The Predator Drilling System has been designed and built from scratch for drilling in today's complex oil and gas applications. It's oil-field tough and it has been designed to take a chunk out of non-drilling time and cost, to reduce manual labor, to enhance safety and to improve drilling performance.

Predator is an integrated drilling system that brings new technology and innovation to the 200,000 lb. rig class. This isn't new technology for the sake of having something new and different. Predator integrates proven new technology and innovations with components and systems that Atlas Copco has used successfully in the oil patch for years. This is why Predator is able to advance the state of the art in this class of oil and gas drill and still maintain the reliability and performance expected from Atlas Copco rotary drills.

The Predator Drilling System consists of three components, a mobile rig, a substructure support system and a pipe handling skate. All three were designed by Atlas Copco Drilling Solutions to work as an integrated system and to be supported by our global network of sales and service centers.

In addition to Predator, Atlas Copco has made a substantial investment in the oil and gas sector of the business. We have expanded the design and engineering test facility, modernized and enlarged the rig assembly bays and have built a new rig up pad for Predator. We have also expanded our Parts Distribution Center and opened a new After Market Support facility.

In this issue, we have a small section dedicated to Predator on pages 11–13. Take some time to look it over.

Here at Atlas Copco Drilling Solutions in Garland, Texas, we're excited about Predator. Come see it at OTC and be sure to check out atlascopcooilandgas.com for the latest Predator information.

Atlas Copco

HOLDING BACK THE

L&S Well Service found that high pressure and a large volume of air is the answer to passing through the Arbuckle formation.

The Arbuckle formation produces oil and gas in Kansas. It is also a strong aquifer, which in the past has been a stopping point for hammer drilling – at least in the production hole size 6¾ or 7⅞ inch (17 or 20 cm). L&S Well Service, out of Cherryvale, Kan., has conquered the Arbuckle with high pressure and volume air.

The Arbuckle is also a water discharge formation. In earlier geological papers written on the formation, it has been described as having columns of oil and gas, which are generally near the top. It has produced 36 percent of the total oil or 2.19 BBO from 21 oil fields over the last 100 years. Oil production peaked in the 1950s at 68 MBO in 1955, tapering off to the point that, today, 90 percent of the wells produce less than 5 barrels per day.[1]

The Arbuckle occurs at depths ranging from about 500 ft (152 m) in southeastern Kansas to more than 7,000 ft (2,134 m) in southwestern Kansas. Arbuckle strata thicken as a whole from north to south and are thickest, up to 1,390 ft (424 m), in the southeastern corner of Kansas.[2]

Jim Lorenz, owner of L&S Well Service, said, “The Arbuckle is very porous

Coal Bed Methane has production staying power

L & S Drilling does most of its work in the Cherokee Basin formation in central Kansas, which has been a developing coal bed methane (CBM) region in the United States for at least 20 years. “The Cherokee group has as many as 13 coal producing seams, but primarily eight CBM producing seams,” said Mark Brecheisen, consulting geologist for L&S Drilling. Most Cherokee coal seams are 1 to 2 ft (0.3 – 0.6 m) thick, with the deepest seam — the Riverton — being 2 to 6 ft (0.6 – 2 m) thick.

Brecheisen said the eastern flank of the Cherokee Basin is about 850 ft (259 m) from the surface, going down to as much as 15,000 ft (4,572 m) on the western flank. He commented that coal is great for holding and producing gas because it is its own source and reservoir rock. The gas is contained within the matrix of the formation which is slowly released. The best CBM producing coal formations are 100 percent saturated and as water is removed from the cleats, more gas is released. He points out a CMB well could easily have a production life of 20 years. “I have actually seen gas production increase five years after a well was first drilled and another that was producing the same volume of gas eight years after it was first drilled,” said Brecheisen.

◄ Workers close the discharge line venting gas through the gauge.

TIDE

with lots of water; it’s like drilling in the bottom of the ocean.” The aquifer is brine to the west. Further east into Missouri, the elevation rises and the arbuckle actually produces fresh water, according to Lorenz.

Air drilling is the method of choice for L&S, and having a dependable booster is critical to the process. Lorenz said, “I have a mud pump, but haven’t used it in a year! I like air.” It’s his goal to finish a hole in a day to prevent “watering out,” or having to stop because the column of water reduces bit force on the rock. Increasing air pressure through the hammer discharges the head of water, allowing the bit to strike rock. L&S carries 2,460 ft (750 m) of 4½ inch (11 cm) Range III pipe with them, but generally doesn’t need to go deeper than 2,200 ft (671 m).

Going deeper into the bore hole puts more water around the annulus of the drill string. The weight of the water at the bit, also called head pressure, requires more air pressure to overcome the head pressure to evacuate water from the hole.

To date, Lorenz said, “I am the only driller I know of who has air drilled a 7⅞ inch (20 cm) gas production well into the Mississippian and Hayes formations.”

According to Jeff White, product support specialist with Atlas Copco CMT USA, “A good guideline is that each foot of water requires 0.5 psi to evacuate the water.” He also pointed out that a good trick to unload the hole if it has filled up with water – in a morning startup, for instance – is to trip out a few sections of pipe, reducing the head pressure on the bit.

L&S operates a new Atlas Copco RD20 drill rig, equipped with a 1,250 cfm, 350 psi air compressor (1,250 cubic ft of free air delivery at 350 pounds per square inch). Once drilling into water, the head pressure begins to build. To evacuate excess water, L&S driller, Dustin Hirrlinger, engages the booster, but he admitted, “I usually crank up the booster early because I can drill faster.” L&S runs a two-stage Hurricane booster, although it is possible to operate the unit in single stage mode in more shallow situations.

The booster sucks air from the rig compressor and any auxiliary compressor and converts it to a higher pressure. L&S runs a 6T 855 62B 2000 Atlas Copco Hurricane booster with their RD20, which can produce 2,000 psi (137.9 bar) with 350 psi (24.13 bar) of suction. At 350 psi suction, the unit produces 2,400 cfm (67.96 m3/min). *(That Hurricane booster model is now known as B18-62/2000.)*

Hirrlinger said, “It is important to know what you’re doing when engaging the booster because the water discharges at such a high pressure.” He emphasized the importance of chaining down the discharge line and starting slowly when unloading the hole. At idle, the Hurricane puts out 1,500 rpm which equates to 600 psi.

Jim Lorenz pointed out the necessity of having a booster, “Drilling a ►

▲ Workers can easily set up and disassemble on a site with the flexible tubing on the Hurricane booster.

◀ Dustin Hirrlinger (right) is Jim Lorenz's right-hand man and is drilling on the new RD20.

7⅞ inch (20 cm) hole takes twice the water that a 4⅞ inch (12 cm) hole will. To lift the water it takes a minimum of 1,000 psi to drill into the Arbuckle 400 ft (122 m). If you don't have the air, you'll lose circulation."

Speed is a big advantage when drilling with air, but Lorenz also said that he can get a straighter hole using air and a smooth-bore stabilizer. "When logging our holes, we have less than a 2 ft (.6 m) deviation where others can have 20 to 30 ft (6 to 9 m)," he said.

Not all of L&S's wells are disposal wells. Lorenz does everything from geothermal wells to gas and oil wells. Lorenz can work for anybody, and has in his 32-year-career, but he likes working with smaller customers and fills in with the big gas companies.

"I like taking care of the customer from beginning to end and that works well with the little guy," Lorenz commented. No matter what the well's eventual use, he has the air power to go to depths of 6,500 ft (1,981 m) with the RD20 and 3,500 ft (1,067 m) with the Atlas Copco T4W.

ON SITE IN KANSAS

Although L&S doesn't drill residential jobs often, as most wells tie into a pipeline, it does happen.

Here, L&S was cleaning a 719 ft (219 m) gas well for a customer's home. When completed, the well produced 25,000 mcf, plenty more than the required 5,000 mcf.

There was an existing gas well that had played out and the homeowner wanted it cleaned. After cleaning out the well's 20 ft (6 m) of casing and open hole of 719 ft (219 m), the L&S crew installed 2½ inch (6 cm) diameter steel casing to total depth.

Hirrlinger said that the gas production zone is in a sand formation called "Cattlemen's Sand."

The casing was placed all the way to the bottom. The last section had holes pre-drilled in the casing to allow the gas to enter the pipe. Above that section is a packer that seals off the gas zone. The packer, made in L&S's shop, is an expanding gasket with shear pins that fall off with the weight of the casing above it, allowing the rubber gasket to expand in the hole.

The crew completed the well by cementing in the casing above the packer and running pipe to the home.

1.Geological Controls on Variable Character of Arbuckle Reservoirs in Kansas: An Emerging Picture; Kansas Geological Survey Open-file Report 2003-59

2. Keroher, R.P., and Kirby, J.J., 1948, Upper Cambrian and Lower Ordovician Rocks in Kansas: Kansas Geological Survey Bulletin 72, 140 p. Cole, V.B., 1975, Subsurface Ordovician-Cambrian rocks in Kansas: KGS Subsurface Geol. Series 2, 18 p.

See us at Booth #8057

Atlas Copco *at the 2009* Offshore Technology Conference

The CaliberXD™ bit is armed with the most advanced and durable polycrystalline diamond inserts in the world. Why rely on anything but the best? Success in the oil and gas drilling industry requires reaching total depth without tripping out and changing the bit. You need to make sure your first shot is the best shot ... with the CaliberXD, it will be.

The B7-41/1000 Hurricane booster is part of an updated range of boosters. This booster is driven by a Caterpillar C7 diesel engine (Tier 3) and is coupled with a Hurricane 4-cylinder single-stage booster block. With 350 psi suction pressure the capacity is 2,400 scfm at a maximum discharge of 1,000 psi. Atlas Copco has extended the standard booster range with additional models at higher pressures, covering flows between 500 – 4,500 scfm and pressures up to 5,000 psi. The seismic compound compressor range has also been extended and is driven by Caterpillar marine engines with sea-water coolers that combine the screw and the Hurricane piston technology.

These extra models meet the demand for higher pressures in the oil and gas industry for applications such as deep hole drilling, pipeline services and well services. For offshore applications Atlas Copco has designed certified containerized boosters including latest technologies and offshore features. As always, Atlas Copco has a focus on aftermarket and service support.

The DrillAir™ range of compressors provides larger air volume with higher air pressure. The new DrillAir compressors are used in deep drilling in oil and gas, deep foundation, and water well drilling, meeting the demands of drilling contractors to drill even deeper and larger holes at the fastest penetration rates while reducing energy costs.

A new 510 psi model offers greater air volume at higher air pressure while being energy efficient with low fuel consumption.

The latest 510 psi model, DrillAir 510, features the XRYS 1220 CD7 and XRYS 1260 CD7, which offer an increased free air delivery of 1,165 – 1,207 cfm. The XRYS 1260 CD7 model compressor also introduces a patent-pending **Drill*AirXpert***, a fully variable regulating system to ensure full control of pressure and flow. The variable system is easily able to provide the exact pressure required when needed, between 300 – 510 psi. It can also be set to provide a regulated flow output of up to 1,500 cfm. With no manual regulating valves and associated lines, the DrillAirXpert has improved fuel consumption by 3 percent.

Mixing it up

Save costs on a job site by implementing a 'mixed fleet' approach — using lightweight hydraulic rigs to do the pre-set and switching to larger rigs for deeper segments of the well.

There's an old adage in the oil patch: "If a rig's drill isn't turning to the right, it isn't making money."

If you consider what a rig does from the time it's mobilized to reach a location until it is moved to the next location, there is much time and money spent on non-drilling functions. Still, these complex and time-consuming non-drilling activities are necessary for productive drilling.

Until recently, drilling a well was considered a continuous process in which a single rig was employed to drill from the surface to total depth (TD). In reality, wells are drilled and completed in segments, and each of these well segments requires different rig capacities to achieve optimum performance and cost control. A contractor's profitability depends on maintaining maximum performance and efficiency from the equipment in each segment of the well-drilling process.

One way that land-based drilling contractors can reduce operating costs is to adopt a "mixed fleet" approach – use lightweight hydraulic top-drive rigs to perform pre-set casing work and drill shallow exploration and production wells. Then, when the larger rig moves on location, it can nipple up and

DRILLING AND NON-DRILLING OPERATIONS ON A NEW SITE:

Mobilization— Transporting the rig and related equipment to the location
Rig up— Setting up the rig and related equipment to drill
DRILLING **SURFACE**— Drilling the surface hole
Tripping pipe— Pulling pipe out of the hole to set casing
Setting casing— Installing surface casing in the drilled hole
Cementing— Cementing casing and dry time
Tripping pipe— Tripping pipe into the hole to begin drilling
DRILLING **INTERMEDIATE**— Drilling the intermediate hole
Tripping pipe— Tripping pipe out of the hole to set casing
Setting casing— Setting intermediate casing in the drilled hole
Cementing— Cementing casing and dry time
Nipple up— Rigging and pressure testing the BOP
Tripping pipe— Tripping pipe into the hole to begin drilling
DRILLING **PRODUCTION**— Drilling the production hole to TD
Tripping pipe— Pulling pipe out of the hole to set casing
Setting casing— Installing casing in the drilled hole
Rig down— Tearing down the rig and related equipment to move
Mobilization— Transporting the rig off location and to the next well

immediately begin drilling the deeper segments of the well.

With this approach, both rigs perform at maximum efficiency, while each completes its part of the drilling plan.

OPTIMUM RANGE

Every drilling rig has a range of optimum performance. Outside that range, performance drops off and cost-per-foot increases. For example, a 1,000 hp to 1,500 hp triple is designed to drill holes in the 10,000-ft to 20,000-ft (3,048 – 6,096 m) depth range. When it drills shallower holes, it is less efficient because it has more capacity and manpower (and the associated cost) than is required for the job.

With lighter weight, mobile drills in the 700-hp to 900-hp class, contractors can drill shallow wells from spud to TD and support larger rigs by drilling pre-sets for deeper holes. These smaller rigs and their related equipment mobilize quickly. Fewer trailer loads to bring on location can translate into lower cost. Typically, within one to four hours upon reaching the site, lightweight, mobile drills can be effectively drilling.

In many instances, contractors are able to drill and set surface with these "pre-set" rigs in less time and with fewer personnel than it takes to mobilize and rig up a larger conventional rig. With pre-sets complete, a large rig can move on location and start drilling within its range of optimum performance and efficiency.

IN THE FIELD

Some contractors have been able to save time and money by drilling surface and intermediate holes with air drilling. In the Uintah Basin, Pro Petro Services has been using an Atlas Copco RD20 rig to drill pre-sets for larger rigs. "We typically drill 200 ft to 1,500 ft (60 – 457m) cased at 13⅜ inches (34 cm), and 1,500 ft to 3,500 ft (457 – 1,067 m) cased at 8⅝ or 9⅝ inches (22 or 24.4 cm)," said operations manager W.D. Martin. These wells are typically drilled with air, using the rig's on-board compressor with an auxiliary compressor and a booster.

"Prior to using the Atlas Copco RD20, our conventional rigs were drilling down to the bird's-nest zone and losing 80 percent of their water or mud circulation pressure," Martin said. Using high-pressure air, the RD20 drills through the bird's-nest zone without losing circulation. When the surface and intermediate holes are cased and cemented, the conventional rigs come in to drill the wells to 6,500- to 8,000-ft (1,981 – 2,438 m) TD. Martin reported that his company has saved five to six days per well and drilled 10 to 15 more wells per year using the mixed fleet approach.

INCREASING EFFICIENCY

Lightweight, top-drive rigs can offer improved performance and cost efficiency in several areas:

• **Mobilization cost:** Carrier- ►

Lightweight rigs, like this Atlas Copco RD20, can move on a location and rig up with four to six people in one to four hours. It can take a crew 24 to 72 hours to rig up a conventional rig, as shown below.

mounted, self-contained rigs are highly mobile and can generally transport to and from location with simple highway permits. They can attain highway speeds and are excellent in off-road conditions, even in mountainous and remote terrain. For pre-set work, they usually require six to 10 loads to complete the location. They create a relatively small footprint and can work in tight locations.

A conventional rig may consist of up to 30 loads to build a location. Many of these loads require special weight and dimensional permits and are restricted to specific routes and times of day.

•**Rig-up time:** Lightweight rigs move on location and rig up, with four to six people, in one to four hours. Simple air drilling locations are usually turning to the right in one to two hours with a single crew. More complex mud drilling locations can be set up and drilling in three to four hours. In comparison, a conventional rig can take 24 hours to 72 hours, with a larger crew, to rig up with the related equipment.

•**Setting surface casing:** Pre-set rigs can set Range III casing at about the same rate as a conventional rig. Most lightweight rigs set surface casing with the drilling crew. These rigs are readily adaptable to hydraulic catwalks or lay-down arms that allow "hands-free" casing handling. They handle casing with the top drive and feed system. Casing is lifted and set using special elevators attached to the top drive. Rotation torque is set to match casing torque specifications. The top drive spins the casing together and stops when reaching the pre-set torque. Using the top drive and feed system allows the casing to be pushed, pulled, rotated and even circulated. Traditional rigs handle casing with the drawworks and traveling block. Casing is hanging from the block so it must be guided and controlled by the deckhands. Casing is spun together with additional tooling and cannot be pushed, rotated or circulated. In many cases, large rigs contract a casing service to come on location to set strings of casing.

•**Tripping pipe:** Today's lightweight rigs handle 30-ft or 40-ft (9 – 12 m)drill pipe and can be adapted to a wide range of pipe handling equipment. Most are lay-down rigs that do not stand pipe in the derrick. They are readily adapted to "hands-free" pipe-handling systems. A conventional rig can handle triple stands of pipe during a trip. This is faster than the lay-down systems on lighter pre-set rigs. This system, however, requires a worker up in the derrick and manual labor with heavy loads.

•**Rig down:** Lightweight rigs can rig down and move off location in one to four hours, including the related equipment. A conventional rig will usually take 24 to 72 hours to rig down.

The objective of the "mixed fleet" approach is not to replace larger, conventional rigs with smaller rigs. Rather, it is to utilize both rigs within their optimum performance ranges to increase drilling and non-drilling performance, while reducing overall cost per well.

DHD 1 09

Predator™

Tough drilling issues are no match for the newly launched Atlas Copco Predator Drilling System.

The Predator™ Drilling System is a new generation drill for the oil and gas industry and is the latest addition to the Atlas Copco drilling fleet. This innovative drilling system includes three components: a mobile rig, a substructure and a pipe handling skate.

"These three components are designed to work together to achieve a new benchmark in drilling performance, operating cost and safety," said Ron Buell, business development manager, deephole drills, Atlas Copco Drilling Solutions, Garland, Texas. The Predator drill rig is underpinned by a 30-year history and an experience base of over 300 rigs in the global oil patch.

The Predator Drilling System is designed to be exceptionally mobile and quick to rig up. "The main focus is to reduce non-drilling time and cost, as well as improve performance and energy efficiency, and enhance safety," Buell stated.

"With an actual working hookload capacity of 200,000 lb (90,719 kg), Predator has the strength and capacity to drill vertical, directional and horizontal wells in today's global CBM and natural gas basins," stated Kevin Moran, engineering project manager with Atlas Copco Drilling Solutions.

UNIQUE APPROACH TO DESIGN

Atlas Copco's engineering and marketing team took a non-traditional approach in their design process for the Predator Drilling System. Rather than focusing on the more obvious product features, the team chose to develop a new product with measurably greater value (financial return) than current drilling systems.

"A drill in this class normally spends less than half of its time actually drilling holes," said Moran. "The rest of the time is spent mobilizing, rigging up, handling pipe and standing by while other operations are completed. We took all of this into consideration during the development process. In addition to designing a rig to drill oil and gas wells to a specific depth, we focused on reducing non-drilling time and cost, increasing operating performance, and enhancing safety."

> "The main focus is to reduce non-drilling time and cost, as well as improve performance and energy efficiency, and enhance safety."
>
> — Ron Buell, business development manager, deephole drills Atlas Copco Drilling Solutions

Included in the enhancements created by this design is a virtually hands-free breakout and pipe handling system, which requires almost no manual intervention. This eliminates the need for personnel in the mast during drilling operations. Another enhancement is a hydraulic floor crane on the substructure to assist in rig up and drilling operations. The crane reduces heavy lifting and additional manual intervention.

The breakout and pipe handling system is virtually hands free. The console and monitor can be mounted on the work floor or in a control cabin.

The carrier has a full-width, low-profile cab with the amenities found in conventional trucks. The carrier drive also has the ability to drive in "creep mode," a feature that gives the driver precise control and vehicle placement in off-road or extreme driving conditions.

The Predator substructure, an integral part of the drilling system, serves as a strong, structural base for the rig.

MIXED FLEET APPROACH

"The Predator's mobility, quick set-up time, and powerful drilling system make it a perfect fit for the mixed fleet approach," Buell said.

The mixed fleet approach allows land-based drilling contractors to capitalize on the strengths of two types of drilling rigs: lightweight mobile rigs and deep-hole conventional rigs. The lightweight hydraulic top-drive rigs drill surface holes and pre-set casing. Then, the larger rig follows and drills the deeper segment of the well. The benefit is that both rigs perform at maximum efficiency. Each rig completes its part of the drilling plan in the least amount of time and at the lowest possible cost. This approach results in a considerable savings in mobilization costs, rig-up time, setting surface casing, tripping pipe, and rig down.

COMPONENT OVERVIEW
HYDRAULIC CARRIER DRIVE

The Predator's unique single-engine hydraulic carrier-drive system is an innovative use of the rig's existing power systems. The carrier has a full-width, low-profile cab with all of the amenities found in conventional trucks. The single 950 hp (708 kw) engine powers both the carrier and the drill, utilizing shared components rather than a second engine plus drive train. This design greatly reduces weight, as well as time and cost for maintenance. In drive mode, the engine consumes less than half of its rated power and is capable of full torque at any time, regardless of speed. The hydraulic drive, coupled with a clutch and manual transmission, provide an exceptionally wide range of power and speeds. "We designed the Predator to drive exactly like a conventional truck or drill carrier," said Moran. "The drill is equally effective on flat land or mountainous terrain and can maneuver both with ease."

The hydraulic carrier drive employs a dynamic braking system, which is both quiet and efficient, unlike conventional braking systems. It also has the ability to drive in "creep mode," a feature that gives the driver precise control and vehicle placement in off-road or extreme driving conditions.

SUBSTRUCTURE

The Predator substructure, an integral part of the drilling system, serves as a strong, structural base for the rig. "It is designed to rig up rapidly, with reduced manual labor and assembly," Buell said.

The table, master bushing, hydraulic slips and iron roughneck are part of the substructure and travel with it. With four hydraulic blocking jacks, leveling is simple and fast. An electric-hydraulic power system deploys the drive-on ramps and catwalks.

The BOP stack can be transported with the substructure. A handling system sets up the BOP after the surface casing has been set. A hydraulic crane, with a telescoping boom, assists with rig up and utility lifting during drilling operations. The crane boom, operated by remote control, can be positioned over hole center or can reach off the work floor to pick up loads from the ground. The main air / mud manifold is also located on the substructure for quick ground level hook up.

"We designed the Predator to drive exactly like a conventional truck or drill carrier. The drill is equally effective on flat land or mountainous terrain and can maneuver both with ease."

— Kevin Moran, engineering project manager, Atlas Copco Drilling Solutions

The large 190 ft² (17.6 m²) work floor is designed to provide ample working space and is configured with drill-crew efficiency and safety in mind. The two access stairways are hinged at the top so they adjust to substructure height, while keeping the bottom end firmly on the ground. Because the substructure is contained in a single load, it can be deployed with less assembly and manual labor than most other substructures, reducing non-drilling time and cost.

SKATE

The Predator skate is a complete pipe handling system designed to work with the Predator rig and substructure. It is a single skid-mounted load, which is positioned directly behind the substructure and attached to it. The skate is designed to handle drill pipe, collars and casing. It can handle Range II (30 ft or 9 m) or Range III (40ft or 12 m) oil field drill pipe as well as Range II or Range III lengths of casing up to 24 inches (610 mm) in diameter.

"Being able to use Range III drill pipe can save a lot of time and money over Range II pipe changes," said Shane Lein, product manager deephole drilling equipment, with Atlas Copco Drilling Solutions. Hydraulic jacks make set up and alignment quick and simple.

The skate has foldout pipe racks on both sides. These racks have hydraulic jacks so pipe will roll onto the skate when drilling—and off the skate when tripping out. The skate can be supplied without racks so hydraulic pipe tubs or simple A-frame racks can be used to load and unload the skate.

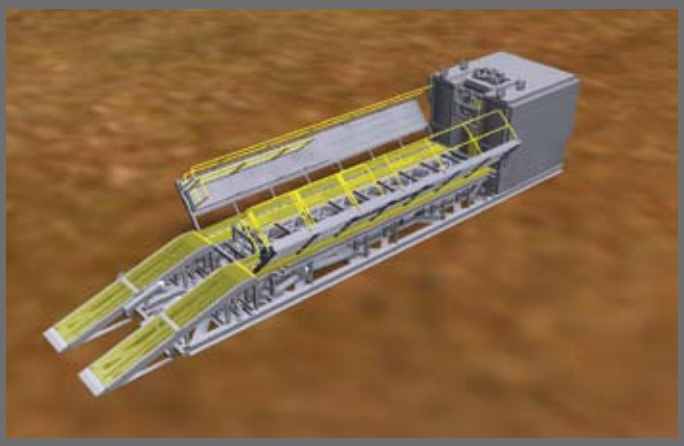
The control system for pipe handling can be located on the work floor and/or at ground level. Usually, a crewmember will handle the loading operation on the skate and elevate the pipe to a fixed position behind the work floor. The driller will grip the pipe and extend it to meet the spindle for make up. After the joint is made up, he will open the clamp and retract it. Then the crewmember will lower the trough and load the next pipe from the racks.

Unlike manual pipe handling systems, the Predator skate doesn't get tired and is designed to maintain a constant, fast pipe-handling speed hour after hour.

CONCLUSION

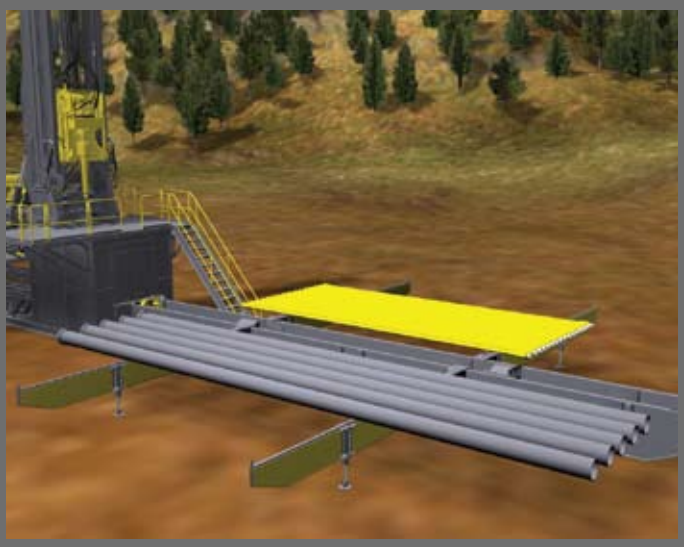
Atlas Copco Drilling Solutions has invested several million dollars in the Predator Drilling System design, manufacturing, testing and support resources. Every component has been thoroughly engineered and tested to be certain it operates as designed. Combined with the global sales and service facilities of Atlas Copco, which provide unmatched customer support, the Predator Drilling System is truly a significant advancement in the oil and gas market.

DHD 1 09



The sub-structure is a single load designed to rig up rapidly with reduced manual labor and assembly.

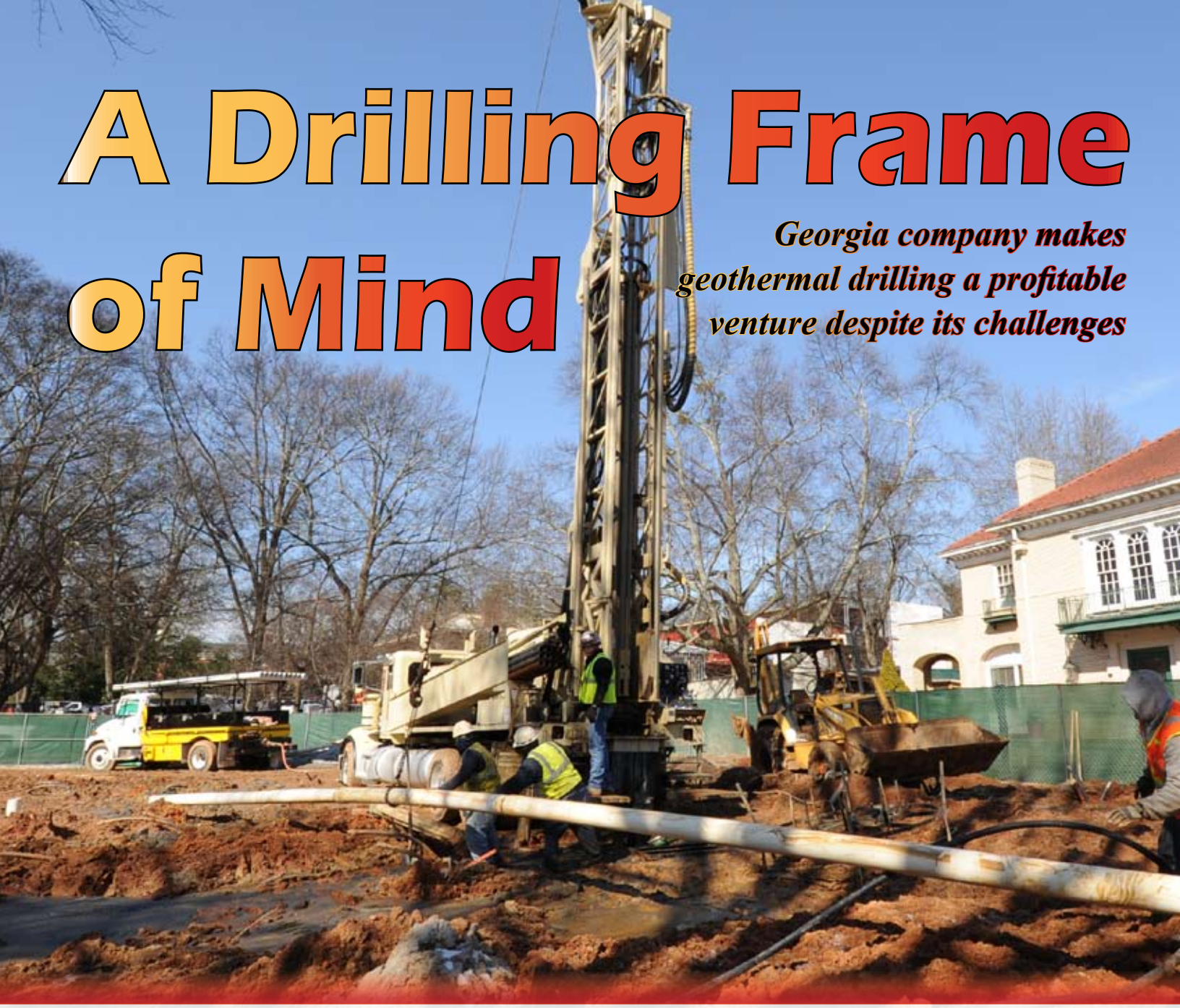
The large work floor is designed to provide ample working space and is configured with crew efficiency and safety in mind.



The PREDATOR SKATE is a complete pipe handling system, designed to work with the PREDATOR rig and substructure. It is a single skid-mounted load positioned directly behind the substructure and attached to it. The skate is designed to handle drill pipe, collars and casing. It can handle Range II (30') or Range III (40') oil field drill pipe as well as Range II or Range III lengths of casing up to 24 inches (610 mm) in diameter.

A Drilling Frame of Mind

Georgia company makes geothermal drilling a profitable venture despite its challenges



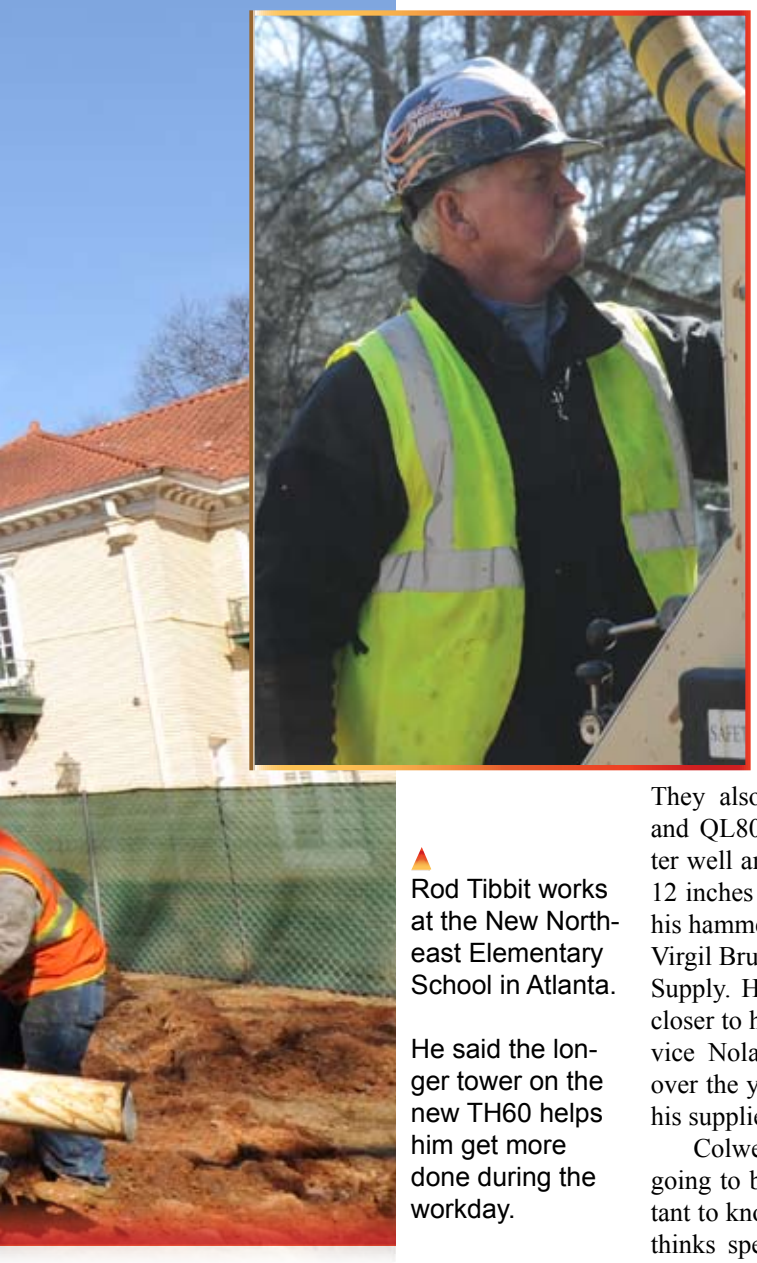
On a cold spring morning on a drill site in Atlanta, the day after a 6-inch (15 cm) snowfall, steam rose from the flushing water ... a reminder that the earth is a constant heat source under our feet. Drillers are considering this fact more seriously as they become more creative about how to sustain their businesses in today's economic downturn. Many are looking at the possibilities of geothermal drilling. Middle Georgia Water Systems of Zebulon, Ga., is a leader in geothermal work and has many ideas on how it can be done profitably.

There is a fundamental difference in the approach to geothermal work versus water wells. "Water well drillers make money developing a hole. With geothermal, it's all about production. Water wells are gravy work compared to geothermal projects," said Jerry Colwell, owner of Middle Georgia.

Colwell purchased his first drill rig in 1974 and has bought 25 to 30 more over the years, some years purchasing two or three at a time. Colwell currently has nine rigs in his fleet, two dedicated to geothermal work, but he rotates his fleet for whatever the job. Today his fleet of Atlas Copco drills includes two T4W rigs, six T3W rigs and one TH60 drill rig. Four drills in the fleet are outfitted with mud pumps as Colwell's working territory is divided by a fault line requiring both air and mud drilling.

Colwell stays close to home for residential water well work, but travels throughout the south for commercial, government and geothermal work. He says to get into geothermal work requires the right crew with a mindset for efficiency. Colwell said, "It's tough work — setting and pulling casing, placing the loop and hustling to the next hole. Bam, bam, bam ... day after day, week after week."

"Being successful [drilling] 500 ft (152 m) a day is hard to do; at 1,200 ft



Rod Tibbit works at the New Northeast Elementary School in Atlanta.

He said the longer tower on the new TH60 helps him get more done during the workday.

(365 m) a day, you'll make money," he emphasized. If the drilling isn't going well, it doesn't take long before the project isn't profitable, even costing money. "We have been called in to jobs where others have pulled off. I can say we have never left a job once we started. That's hard to do, but necessary for long-term business success," said Colwell.

Colwell compares geothermal work to quarry production work. Daily footage is where you make money and you have to keep the same customers happy. Generally, his projects are bid to a loop contractor or a heating and cooling company. He pulls on the job and installs the loop field for someone to come in after him to complete the project.

At 200 ft (61 m) of drilled hole per ton of heating and cooling, some of the jobs Middle Georgia works on are very large. Hole depths range from 150 ft (46 m) to 400 ft (121 m). Some jobs have 80 to 90 holes, but there are those that have 400 holes, too. "On those bigger jobs, we like to get five to six holes a day, but some days you may only get one," said Colwell.

For geothermal projects Middle Georgia uses QL50 hammers with 5½ inch bits. They also use Atlas Copco QL60 and QL80 model hammers for water well and commercial work up to 12 inches in diameter. Colwell buys his hammers, bits and drill rigs from Virgil Bruinekool at Noland Drilling Supply. He could buy consumables closer to home, but the personal service Noland has provided Colwell over the years has kept him loyal to his supplier.

Colwell advised that if you're going to bid a job, it is very important to know the formation. He also thinks specializing as a driller and not attempting to do what you don't know is wise. He likes subcontracting to others for his work, saying "I think it's better to do one thing really well." This also means he is not competing against a company that may be his customer.

At one time, geothermal work accounted for about 20 percent of Middle Georgia's business. Today that number is closer to 50 percent. The company has four employees bidding jobs, which is a long way from the days when Colwell said he got work by driving down the road, looking for new houses popping up. "About 90 percent of our work comes from referrals. The HVAC and ground-source heat pump guys send us lots of work because they know not everyone can do this," said Colwell.

He emphasized that those who do want to get into geothermal work need to remember it is more like production drilling than water well drilling. Expenses all being the same – fuel, drill payments, labor, tooling – the cost per foot is roughly half what can be made developing water wells. "You have to be organized and efficient and have good people," said Colwell.

Rod Tibbit is one of Middle Georgia's key drillers. Kevin Colwell, vice president of operations for Middle Georgia, said Tibbit fits the personality of a good geothermal driller. "He is a real company man who is strong willed, organized and tough. He thinks ahead – two steps head – and is real project-minded."

According to Tibbit, he first looks at a job and thinks about how he can make it more efficient. "Anything I can do to speed up the process makes a difference," said Tibbit.

The longer tower on the new TH60 gives Tibbit more room to work with the casing. "With the longer tower, I can pull longer casing. That's a great benefit," he said. The crew installs about 60 ft (18 m) of PVC casing to support the overburden while drilling and then extracts the casing in one piece when the hole is finished. This speeds the process by allowing them to pull the casing faster, lay it down with the winch and move to the next hole.

Planning out the job in advance, and hustling at certain times, cuts time during the day. Everything equates to footage, in Tibbit's opinion. "Twenty or a hundred feet more by the end of the day, over a month or whatever time you're on the job, all adds up."

Tibbit likes to work hard, as does his three-man crew. One assistant said, "I like to keep moving because it makes the day go faster and it's never stagnant." Another said, "These big jobs are good; it's just good knowing you have a job." Tibbit and his crew also like knowing where the job is every day — a large geothermal job can take months to complete.

The pace Tibbit runs his crew, "keeps everyone on their toes," he said. Like all drilling jobs, when the bit is turning there is less to do, but his crew continues to get the coil in place, move cuttings and, on this particular job, manage the water. "On this job, we can use cuttings from one hole to grout the next, but we also have a Geoloop 50-500 that makes grouting fast," said Tibbit.

"The TH60 is the best drill I've ever run because it's faster and quieter."

—Rod Tibbit, driller

Because the current job is at a school in a residential neighborhood, they are not allowed to operate before 8 am and must shut down for 30 minutes as students leave school.

Another tip to moving faster is to keep the water behind you so the rig has solid footings. "This job is producing 80 to 200 gpm (302 – 757 lpm) per hole, which could create a huge mess and problems with rig stability if we didn't work it right," said Tibbit.

In the nine years Tibbit has been with Middle Georgia, he has always run T3W drill rigs — until now. He is operating the company's new TH60. "The TH60 is the best drill I've ever run because it's faster and quieter," said Tibbit. Because the current job is at a school in a residential neighborhood, the crew is not allowed to operate before 8 am and must shut down for 30 minutes as students leave school.

Barton Malow is the general contracting company on the job. Senior Superintendent Doug Braun manages the project. "The school stays open during the day and reports from inside the school say they are used to the rig and that it sounds much like a vacuum cleaner running in another room."

The New Northeast Elementary school (currently named Morningside Kindergarten Campus) near downtown Atlanta is an example of the direction the country is going with renewable energy construction.

Northeast Elementary is undergoing a major expansion with a new 48,000 ft (14,630 m), three-story building on 1.82 acres of land. Braun pointed out that the small site footprint didn't allow space for a mechanical facility. "Water-source heat pumps work perfectly." Braun said.

The building will be heated and cooled by the new geothermal system that includes 40 ground-source heat pumps located throughout the building, a recovery unit on the roof and two pumps in the basement that will pump 285 gpm (1,078 lpm) through the loop field.

The loop field consists of 56, 400 ft holes located under the front lawn. Although the new school addition being built is modern in construction, the neighborhood consists of stately Atlanta mansions. The current classroom buildings are just that, two mansions side-by-side converted into a school. These will link into the system and continue to house administration and classrooms.

The bore holes are 15 ft (4.5 m) apart, closer than the 20 ft (6 m) spacing normally engineered into the projects Middle Georgia drills, but required because of the tight space constraints. These weren't the only issues on this project.

"It seemed like someone was shutting us down every day the first month on the job," said

◀ The family operation: brother and sister, Kevin Colwell and Karri Colwell, along with aunt, Kay Guy, and owner of company Jerry Colwell.

Tibbit. Braun concurred with that, "The city, EPA and many other agencies were watching us." Groundwater was the biggest problem. The first hole drilled was producing 30 gpm (113 lpm) and the sand filter sized for the job could only handle 15 gpm (57 lpm). To keep the chalky run off out of the popular Nancy Creek, extreme steps needed to be taken.

To solve the problem, Braun designed a comprehensive system. "We now have a maze of filtration in place," said Braun. To start off, they dug a series of four sediment ponds, pumped the water uphill to a series of filter bags large enough to handle the deluge of water, which drained into a natural gravel and sand filter, then finally through hay bales.

"Even after all that was in place, someone reported dirty water running into Nancy Creek," said Braun. "When the EPA arrived to inspect the complaint, they found we were not the problem and actually complimented us on the system we had in place."

The school was the first project of this type for Braun in Atlanta, but he expects there will be many more. "The mayor has made it clear that she wants only green buildings in the future to take advantage of the available credits, but more importantly to save energy," said Braun.

Both Tibbit and Braun see every job as a learning experience. But with each experience, they adjust to make the next job more efficient.

DHD 109

▲Like all drilling jobs, when the bit is turning there is less to do, but his crew continues to get the coil in place, move cuttings and, on this particular job, manage the water.

▼A maze of filtering ponds keep the job from affecting the nearby creek.

Upgrading a Classic Was No Easy Task

TECHNICALLY speaking

By Tom Reeder,
Project Manager
Deephole Rotary Drills

In 2006 the T3W and TH60 underwent updates on several components, some of which are apparent at first glance and others which are not so obvious. Today we call models engineered before this upgrade "classic" T3W and TH60 rigs, while the new models simply have an additional designation indicating pullback weight of 40K for 40,000 pounds (18,144 kilograms) or 70K for 70,000 pounds (31,751 kilograms).

One of the reasons we were compelled to improve efficiency of the drill rig systems was to address the increased heat rejection and additional cooling needs of current diesel engines as a result of new U.S. emission requirements. We needed to be proactive to avoid a never-ending upsizing of our engine installations.

A big visual change in the drill rigs is the larger sheaves in both the 40K and 70K towers. These larger sheaves increase cable life and efficiency. Two additional tower updates add versatility: the 20 inch (0.5 meter) table opening for larger casing and a 30K (13,608 kilograms) winch option.

Another easy-to-spot update was the move away from the pneumatic regulation on the airend to an Electronic Air Regulation System, or EARS. EARS circuit allows better air flow control. For example, the rigs can take a 1,070 cfm compressor down to about 160-180 cfm. This is good in soft formations.

Over the years the T3W and TH60 towers evolved separately. With multiple iterations of the same item, there is a tendency for special products to get lost or left out of engineering efforts. Commonality in the two new towers guarantees that any updates to one rig will benefit both rigs.

Perhaps not as easy to spot, but quite significant, was the incorporation of pressure compensated and load sense valves and pumps into the hydraulic system and fan control circuit. The fan control element of the EARS system more precisely controls the fan speed to the cooling requirements of the compressor and hydraulic oil on both drills, in addition to engine cooling on the T3W. This reduces wasted horsepower by only running the fan at the speed dictated by cooling requirements. The fan circuit now has a dedicated fan pump, which is pressure compensated in order to further improve efficiency.

"Over the years the T3W and TH60 towers evolved separately. With multiple iterations of the same item, there is a tendency for special products to get lost or left out of engineering efforts. Commonality in the two new towers guarantees that any updates to one rig will benefit both rigs."

The new TH60

"The single largest consumer of horsepower on the drill is the airend. We offer the 'in/out box' on T3W and the PTO clutch on TH60 to disengage the airend from the engine not in use. This can save upwards of 100 horsepower."

The single largest consumer of horsepower on the drill is the airend, and it drives the engine selection more than any other component. We offer the "in/out box" on T3W and the PTO clutch on the TH60 to disengage the airend from the engine not in use. This can save upwards of 100 horsepower while mud drilling or tripping pipe and can be a significant energy savings, depending on hole depth. There is a tendency not to disengage the airend on shallow holes because of the time it takes, but those cost savings will add up over time.

The classic 30K units used five pumps to do what we can now do with three. On a new 40K drill, the current main pump supplies oil for the setup functions, jib and winch controls, table slide, carousel, breakout, rod spinner, water injection, and the fast and slow feed. The fan circuit also employs a dedicated pump and motor and the rotation circuit has a dedicated pump and motor. To reduce the number of pumps in the circuit – and to increase hydraulic efficiency and increase feed and winch speeds – we chose to utilize load sense pumps.

One more significant benefit this provided was the ability to idle the machine down and still provide enough oil to run the casing hoist or the fast feed. On the classic machines those functions ran with fixed displacement pumps, and the engine ran at full rpm in order to quickly trip pipe with the rotary head or casing hoist. With the fixed displacement pumps dumping over relief valves, the rig was consuming a lot of horsepower. All five pumps were spinning at maximum rpm and pumping oil over reliefs or running through directional control valves.

Pump operation is totally different on the new T3W and TH60. The load sense pump will not flow oil for which there is no specific requirement. Pressure will build in hoses (when one function is being used but not another), but for any energy to actually be consumed, the oil must flow through that function.

The basic horsepower equation for hydraulic pumps is HP=PSI x GPM ÷ 1714. If you look at that equation, HP (horsepower) equals PSI (pressure) multiplied by GPM (gallons per minute) and divided by a constant 1714, the load sense pump drives down GPM towards zero, and that drives down the HP number as well.

There is no excess pressure building with the load sense pump. The load sense hoses send the maximum pressure the system "sees" back to the compensator and that maximum pressure is what the pump builds to. This affects the horsepower equation as well by keeping that PSI component as low as possible, keeping the HP down proportionally.

These new drills are not the classic T3W and TH60 drill rigs and do not operate quite the same. Remember, the real cost savings occur when the airend is disconnected and the drill is idled down when tripping pipe or even during some drilling operations.

I want to thank those drill owners who were nice (crazy) enough to allow me to operate their brand new drills as well as their older ones. Running both offered me the opportunity for perspective and comparison.

I am impressed with the knowledge of our customers and how open and willing they are to share. Kudos to my colleague, Tim Ledbetter, for the development of this new system. He drove the design of the drills and took the heat until the drills proved themselves in the field.

The new T3W

Business Practices to Live By

Successful family drilling business relies on Atlas Copco equipment to keep customers and employees happy.

Robert Royall is a figurehead in the water well drilling community. He has held many state and regional positions, including current treasurer and former president of the Virginia Water Well Association. He is the current chairman of the services committee for the South Atlantic Well Drilling Association. In these tough economic times, Royall's business insights remind us of best practices in the drilling business, or any business for that matter.

Many drill company owners can relate to the evolution of Royall Well and Pump in Powhatan, Va. Started by Robert's father, Jesse Royall, in 1950, Robert bought the business from him in 1980. Like many drillers, Royall cut his teeth in the business. At age 12 he was doing pump work and was on the drill rig by the time he was 16. Royall remembers driving the company's Truckem 3 rig the day he got his drivers license.

The Royall family got into drilling like many do – out of opportunity. His father had a masonry business running 13 brick crews and needed water on the work sites. More important, he needed to leave the newly constructed homes with a well. So, like most entrepreneurs would do, he bought his first drill, a cable rig. By 1961 Jesse had divided the two businesses and decided to stick with drilling, selling off the masonry business.

Today, Jesse's son Robert Royall operates a modern, well maintained fleet. Of the five drill rigs, two are new Atlas Copco TH60s. The company still has a rig dedicated to bored holes. They also run top-of-the-line support trucks, have a dedicated pump service crew and do well fracking – a common practice in this hard rock region of Virginia – with both hydraulic and mechanical fracking equipment.

When Robert Royall began to purchase the company from his father, he was given a sound piece of advice: "Don't spend what you don't have." At the end of each month, he would give 80 percent of the profits to his father and the 20 percent left was his paycheck. "'Stay in the black' was the best advice my father gave me," remembered Royall.

Royall also said his father was a good sounding board in the early years. "One day, after I finished a tough well, I commented to my father about how glad I was that one was over. He sternly brought it to my attention that I should never look at a drilling job that way because tomorrow there will always be another. He emphasized that I should be thankful I have a job," said Royall.

Royall passed that philosophy on to his employees. "I look at my business like a three-legged stool – company, customer, employee. The company can only stand up with the [help of the] customer and the employees," he said of his people and loyal customers. "We are a big family, with three generations of customers coming back to us and employees that have been with us for nearly 20 years."

SEASONED AND EXPERIENCED

One of those employees is Chris Grosser, who has been on a drill rig for 23 years, starting out in Pennsylvania and spending the last 18 years working for Royall. "You couldn't ask for a better boss," said Grosser. "Robert has updated equipment and if I need something he listens to me. We don't patch [equipment]; Robert does it right."

Like most drillers who have been at it that long and have run many types of drills with various tooling, Grosser said, "You know what is going on in the hole by the sound and feel of the rig." Grosser is the first to tell you, his new TH60 is a different machine.

"It's just a few little things," said Grosser, that give the rig a different feeling, like compensating for the inverted cylinder and knowing gauge differences. It took some time, but it wasn't difficult to adjust.

Up and down feed pressure varies from his old rig. The new rig has its feed cylinder inverted from what was done on his older classic Atlas Copco rig. The inverted cylinder allowed the pullback to be boosted up to 40,000 lb. This gives the rig more pulling power on deep holes.

While drilling in this area the crew rarely goes below 1,000 ft. The deepest Grosser has ever drilled for the company is 1,600 ft and Royall said the company's

deepest well was 1,825 ft.

Grosser likes how quiet the rig runs and that the electronic functions allow him to drill and trip with the rig idled down. The classic requires the full RPM to get full function of hydraulics.

Royall uses Atlas Copco's QL60 hammers and 3½ inch (8.8 cm) drill pipe. Grosser likes using 3½ inch pipe because he can carry more pipe, and with their projected depths the diameter is never an issue. He likes the QL60 and said, "I've tried others and the QL performs longer. Every hammer is good when it's new, but when you're putting 50,000 to 60,000 feet (15,240 – 18,288 m) on a hammer you need it to continue to perform."

Drilling on the grounds at Capital One's West Creek facility near Richmond, Virginia, Royall Pump and Well's drillers Chris Grosser and Brian Bartlett (shown on top of page 20) finished a 1,200 ft (365.7 m) irrigation well in two days. They set 8-inch (20 cm) casing to 63 ft (19 m) then continued to total depth with a 6-inch (15 cm) hole. The well produced 61 gpm (230 liters) after hydro-fracturing.

Robert Royall

MUTUAL RESPECT

Royall's philosophy was passed from his father: "Respect your people and you'll get it back," he said. Royall listens to his people and they follow his lead. Grosser said he has been fortunate that his boss keeps finding him jobs so he can do what he likes to do. Royall said his people do such a good job and care about their work that customers keep coming back.

As times change and the economy evolves, Royall has had to look at diversifying his revenue flow – more commercial projects versus residential – and now the company is doing more geothermal work. Royall and his daughter recently received their geothermal accreditation from Oklahoma State University. But the basic business model has stayed the same: Work hard and let your people do what they do. Don't spend what you don't have. And treat the customer with respect.

A philosophy everyone can agree with.

Clean Speed

Texas drillers work quickly and efficiently with the new Atlas Copco T3W.

Watts Drilling Company of Fort Worth, Texas, manages a clean drill site. The crew has refined its processes to make well drilling a smooth and clean operation. From rigging up to casing and packing a well, the crew is a well organized team. With the purchase of their new Atlas Copco T3W the drilling speed has increased, but it's the incorporation of a pneumatic diverter system that also has allowed the crew to make things more efficient.

Like many companies, Watts' crew prefers to drill a well and set the pump in one day. Depending on the well depth, they can finish up to three wells in a day. In the limestone and shale formations in the area around Dallas and Fort Worth, water well depths average 350 to 450 ft (106 – 137 m) to get the desired flow rate needed by the customer.

Watts recently traded his classic T3W for a new T3W. Driller for the family business, Toby Watts, said the new rig offers clear benefits that have given them drilling advantages over the classic.

"We would burn 105 gallons (397 liters) of fuel a day with the old rig. This one burns just 75 (284 liters)," he said. The new electronic control allows them to turn down the rpm from 1,800 to 1,200 when the power is not necessary. He commented, "The hydraulic improvements on the new T3W make tripping faster at idle than the old rig at full power. I burn 9 gallons (34 liters) an hour idling versus 27 gallons (102 liters) an hour running all out."

Time spent tripping and casing a well at the lower rpm offers fuel savings while maintaining a high level of productivity, according to Toby. The 25 gpm (95 lpm) flow hydraulics on the new rig allows for simultaneous dual control from the operator's console and helper's station at the right. This lets the driller run the rotary head up or down while the helper moves the jib boom, which means that the crew can trip a hole faster because both are working at the same time.

Since purchasing the rig last fall, Watts has drilled 36 wells with the new T3W, which Toby thinks was done faster than with his old rig. "With the old rig we would drill about 140 ft (43 m) an hour and with the new rig, we can drill about 80 ft (24 m) faster," said Toby.

Toby also likes the two-speed head on the new rig. "It smoothes the drill out when you're deep; there's no jerkiness on the bottom. There is so much more control."

Drilling with the new rig is a posi-

tive experience for Toby, and his brother, Tim, who manages the company. "This has traditionally been table-rig country because of the connection to the oil and gas industry," said Tim.

"I don't know why anyone would want to run table rigs [with the efficiencies on the new T3W]."

ALL IN A DAY'S WORK

In its goal to complete a hole in one day, Watts' organized crew benefits from the speed of the new T3W, but also from its incorporation of a pneumatic diverter system, installed by Atlas Copco distributor Venture Drilling Supply, and the resulting clean site.

The diverter keeps the well head dry and clear of mud and cuttings. "Without the diverter it's a real mess setting the pump on the same day," commented Toby.

The pneumatically expanded ground seal of the diverter makes for a fast setup. The crew spuds in far enough to allow the rubber flange to close around the drill pipe. Brackets attach the diverter assembly to the rig. These brackets are adjustable up and down by moving lock pins.

Once the pins are set to the proper height, the pneumatic assembly can be inflated, sealing the assembly to the ground. Stripper rubber around the drill string completes the seal. Discharge piping is easily attached with clamps and manually rotated to direct the cuttings and no additional chaining or securing of the discharge line is necessary.

If drilling on a slope, the crew inserts a 4-foot section of steel casing with a plate welded near the top into the well. This keeps a tight seal between the plate and the pneumatic assembly.

To complete a well in this area, Watts uses 4½ inch (11.4 cm) PVC casing in a 7⅞ inch (20 cm) well. The formation is mostly limestone and shale and drills very easily, averaging 8 minutes per 20 ft (6 m) rod. On the 420 ft (128 cm) well photographed, Toby was expecting 10 to 15 gpm (38 – 57 liters per minute) but got closer to 40 gpm (151 liters) when completed.

From rig up to setting the casing, the four-man crew acts as a team, with very little communication needed. Within a few hours the crew is moving off the job, leaving only a pile of foam a short distance away from the work site, which will disolve in a couple of days. And the team is thinking how nice it was not to work in it.

DHD 109

Drilling in the limestone formation, Watts' crew was drilling about 8 minutes per 20 ft (6 m) rod. The 7⅞ inch (20 cm) hole drilled 420 ft (128 m) will produce 35-40 gpm when complete. Below, the crew reduces labor by hoisting a ¾-yard-bin and dropping pea rock down a slide from a backyard play set. The PVC-cased well is packed with 150 ft (46 m) of gravel off the bottom, then sealed with a bentonite mix. The surface is sealed to 15 ft (55 m) of the surface.

The Predator™ Drilling System

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