Benefits of **Dual Rotary Drilling** in Unstable Overburden Formations

Retrofitting bridge foundation piles with Foremost DR-24

TABLE OF CONTENTS

Benefits of Dual Rotary Drilling in Unstable Overburden Formations

1 INTRODUCTION

THE DUAL ROTARY DRILLING CONCEPT WAS DEVELOPED by Barber Industries and commercialized with the introduction of a DR (Dual Rotary) rig in 1979. In 1993, this technology was acquired by Foremost Industries, LP of Calgary, Canada.

The Dual Rotary method has been proven repeatedly where unconsolidated formations (sand, gravel, cobbles, and boulders) make it difficult to drill a cased hole using conventional drilling techniques. The versatility of this unique drilling rig makes it one of the most efficient and cost effective methods for drilling holes in difficult formations.

The primary distinguishing feature of a Dual Rotary drill rig is a lower rotary drive that is used to advance steel casing through unconsolidated overburden. Rotational forces are transmitted to the casing via power-operated jaws. A carbide-studded shoe, welded to the end of the first piece of casing, enables the casing to cut its way through the overburden. A top drive rotary head simultaneously handles a drill string equipped with either a down-the-hole hammer, drag bit or rolling cone bit to drill the center.

Initially, the Dual Rotary technique was perfected for use in waterwell and construction applications. Foremost continues to refine the Dual Rotary concept and in recent years has introduced new DR models and design features that have improved performance and broadened its range of applications. Today, Dual Rotary rigs operate very successfully in Africa, Australia, New Zealand, Canada, Europe, Mexico, Korea, Taiwan, South America, Trinidad, El Salvador and the USA.

This paper briefly addresses major overburden drilling methods and explains the important features and benefits of the Dual Rotary drilling method.

2 BACKGROUND

THE CABLE TOOL (PERCUSSION) METHOD OF DRILLING HOLES has been used successfully for overburden and hard rock drilling for centuries. In 1948, Wendell Reich (USA) is credited with revolutionizing the well drilling industry with the development of a top drive rotary rig with hydraulic pull-down capabilities. The next major advancement in drilling productivity came with the introduction of the down-hole hammer. These two events contributed significantly to the state of hard rock drilling as we know it today. However, technical progress in overburden drilling has not been as spectacular.

Drilling holes in overburden and unconsolidated formations, due to unpredictable variations, continues to present drillers worldwide with challenges such as loss of circulation, boulders, unstable walls, crooked holes, aquifer contamination and heaving sands. While a variety of overburden drilling methods exist, historically none has been consistently able to overcome all of these challenges. In 1979, Barber Industries, in conjunction with Wendell Reich, conceptualized and built a rig that could simultaneously drill a hole and set casing under the most difficult of drilling conditions and subsequently introduced the first Dual Rotary drill rig.

3 MAJOR DRILLING SYSTEMS

THERE ARE A VARIETY OF COMMONLY USED TECHNIQUES for drilling in formations that require hole stabilization. The best method in any one situation is a function of the equipment available, ground conditions, environmental considerations, and operator expertise. The major overburden drilling systems that have been successfully used are:

- **CABLE TOOL (PERCUSSION/DRILLING AND DRIVING)**
- **ROTARY DRILLING UTILIZING BENTONITES OR POLYMERS (OPEN HOLE METHOD WITH 'MUD')**
- **ROTARY DRILLING WITH CASING HAMMER**
- **ROTARY DRILLING WITH UNDER-REAMING (ECCENTRIC/CONCENTRIC)**
- **THE DUAL ROTARY DRILLING METHOD**

3.1 Cable Tool (Percussion/Drilling and Driving)

Percussion drilling is still used effectively in many parts of the world. Cable tool drills are also commonly known as 'churn' drills or 'spudders'. A weighted string of drilling tools attached to hoisting cable is repeatedly lifted and dropped. The force of the impact crushes the material at the bottom of the borehole. Periodically, the crushed material is cleared using a bailer.

When drilling in unconsolidated formations with a cable tool drill, a casing is often advanced to keep the hole open. The casing is advanced via repetitive percussive blows on top of the casing. Typically the cable tool can only perform one function at a time and the driller alternates between drilling the hole and advancing the casing, switching at various intervals.

Advantages:

- *Low capital investment*
- *Low maintenance and operational costs*
- *Minimal cross-contamination*
- *Water is the only media required for cuttings removal*
- *Large diameter holes can be drilled*

Disadvantages:

- *Drilling is slow in hard formations*
- *Boulders are difficult to drive casing through, often requiring the use of dynamite*
- *Casing penetration rates decrease with depth in a given formation*
- *Casing retrieval is slow*
- *Noise and vibration can be significant and of special concern when drilling in populated areas or near sensitive structures, and can have longer term negative impact on operator hearing*
- *Shortage of experienced cable tool drillers*

3.2 Rotary Drilling (Open-Hole Method with 'Mud')

It is possible, in some situations, to keep the hole open while drilling without the benefit of casing.

3.2.1 *Rotary Drilling with Bentonites (Mud)*

Bentonites and synthetic stabilizers are mixed with water and circulated in the borehole. The resultant fluid, commonly referred to as mud or drilling mud, is used to cake and stabilize the borehole wall. The mass of the fluid also provides pressure in the hole, which helps to keep it open.

The drilling fluid is circulated down the hole through the drill pipe, where it exits through ports in the bit. The fluid (mud) flushes the cuttings away from the face of the bit and carries them up the annulus to the surface. Reverse circulation with mud is also possible. In either case, once the mud reaches the surface, it feeds into a settling tank where the cuttings are separated from the mud before it is circulated down the hole again.

Advantages:

– *Hole penetration is very fast is some clay, sand and shale formations*

– *No temporary casing is required*

– *Fluid pressure in the hole can help control heaving sands*

– *Low horsepower requirement*

Disadvantages:

– *Requires mud mixing equipment and dug pits or metal tanks for circulation*

– *Requires significant amounts of water on location to mix initially and maintain circulation*

– *Requires a fundamental knowledge of bentonites and additives needed to achieve adequate penetration rates and stabilize formations*

– *More difficult to identify water bearing zones, especially in low flow formations*

– *Loss circulation zones can cause aquifer contamination and dramatically increase bentonite costs*

– *Mud may plug the aquifer and cause decreased production*

– *Driller still bears the risk of hole collapse or swell, resulting in possible loss of drill string or jamming of casing during installation*

– *Disposal of mud after hole is completed can be inconvenient and costly*

– *Freezing temperatures make working with mud more difficult*

3.2.2 *Air Rotary Drilling with use of Foams and Polymers*

This method involves rotary drilling with the injection of stabilizing polymers into the air to seal off potential ground hazards that would disrupt the stability of the hole. The foam also helps lift the cuttings, allowing proper evacuation at lower uphole velocities.

Advantages:

– *Hole penetration is very quick in suitable formations*

– *Inexpensive under appropriate conditions*

– *Simple set-up*

Disadvantages:

– *Limited to relatively stable formations*

3.3 Rotary Drilling with Casing Hammer

A casing hammer is a well-established alternative for advancing casing in situations where the hole cannot otherwise be kept open. A rotary top drive rig may be equipped with a casing hammer powered by compressed air, hydraulic or mechanical power that drives the casing as drilling progresses.

Typically, a DTH hammer or tri-cone bit is used to open a hole ahead of the casing and is then retracted inside the casing while the casing is driven with the casing driver. The striking action of the casing hammer can be reversed to aid casing removal.

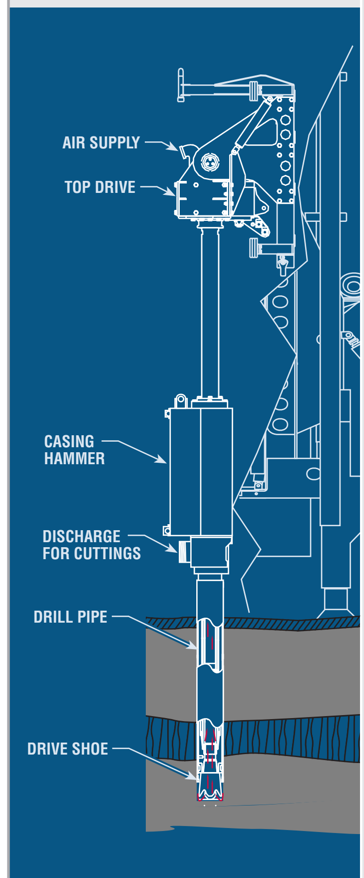
Advantages:

- *Easily adapted to many top drive rigs*
- *Very good penetration rates in certain formations, such as sand, clay and gravel*
- *Casing can be hammered through most overburden formations*

Disadvantages:

- *Limited in size and depth of hole*
- *Casing penetration rates decrease with depth in a given formation*
- *Difficult to drive casing through boulders, which may require dynamite to remove*
- *Hammering is destructive to casing and casing welds*
- *Risk of crooked holes when driving casing in cobbles and boulders*
- *Adds significant cost and weight to a rig*
- *Casing hammer can be in the way when drilling open-hole*
- *Creates significant vibration and noise pollution when operating*
- *Adding additional lengths of pipe and casing is difficult*
- *Awkward to weld casing*

Figure 1



Overview of casing driver system

3.4 Rotary Drilling with Under-Reaming

Under-reaming systems are another way to advance casing through overburden, and are especially useful where suspended boulders are present in the formation. Under-reamer bits are available in a variety of diameters, and cost more than conventional bits of comparable size. The price gap widens as diameter size increases. For example, very large diameter under-reamer bits that might be used in a municipal waterwell or construction foundation application can be prohibitively expensive, making drilling methods that employ conventional tooling more lucrative. There are two basic under-reaming systems available; one uses a special eccentric under-reaming bit and the other uses a concentric bit, which is locked into the casing shoe.

The eccentric system features a special retractable bit that cuts a hole that is larger than the casing shoe, allowing the casing to follow the bit down the hole. The bit is attached to the drill string and inserted into the casing in the closed position. Once it is in place just ahead of the casing, the bit is opened. As the drill string is rotated, the under-reamer bit cuts a hole larger than the casing's outer diameter. At the same time, a striker hits a lip on the inside diameter of a special casing shoe to help drive the casing downward.

Concentric systems utilize a bit that is smaller in diameter than the casing shoe. However, the bit can be locked into the casing shoe. As a result, the downward force of the hammer blows is transmitted through both the bit and casing shoe enabling the drill rod and casing to advance simultaneously.

When total cased depth is reached with an eccentric system, the under-reamer bit is withdrawn and a conventional down-hole bit is then installed to continue rock drilling. With some concentric systems, the bit does not have to be withdrawn as it can be unlocked from the casing shoe and advanced deeper.

Note that the presence of the striker lip on the inside of the special under-reamer shoe causes a diametrical reduction when switching over to open-hole drilling. If the striker lip is 1/4" (6.35 mm) thick, for example, the inner diameter is reduced by a total of 1/2" (12.7 mm). If a liner or screen is being installed beyond the casing bottom, its maximum diameter is limited to the ID of the under-reamer shoe. This may also be a problem in applications where the intent is to grout in a smaller casing in the rock, because the resultant annulus may be insufficient to satisfy regulatory authorities.

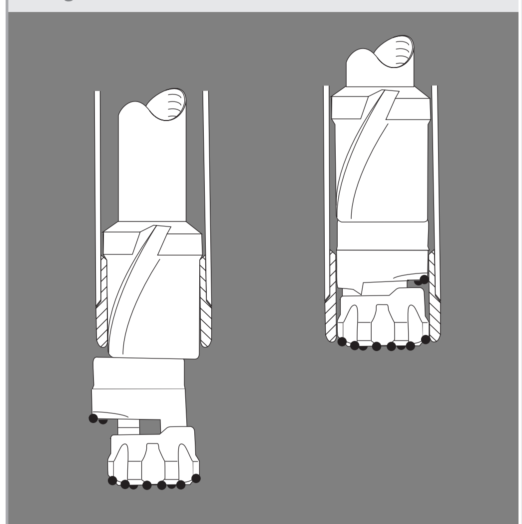
Advantages:

- *Adaptable to any top drive drill*
- *Casing can be advanced through boulders or hard formations*
- *Relatively inexpensive for smaller size holes (6" –10" or 152 – 254 mm)*

Disadvantages:

- *Drill tools are expensive and costs increase dramatically as diameter increases*
- *Distance between the bit and the casing shoe is fixed*
- *Since the bit position is mechanically fixed, it is not uncommon to have the bit clogged by heaving materials, making the bit impossible to retract, in which case, the casing may have to be jacked out entirely to recover the tools*
- *Hydraulic jacks are needed for casing retrieval*
- *Eccentric bits can 'walk' on boulders causing the hole to become progressively more crooked*
- *Adding additional lengths of pipe and casing is difficult*
- *With most eccentric and some concentric under-reaming bits, the driller must trip out and change over to a conventional bit to continue open-hole drilling after reaching bedrock*
- *Bit is designed to be used with air hammer, which may not be suitable in some formations such as clay*
- *Hole diameter is reduced when switching over to open-hole due to the casing shoe's internal shoulder*

Figure 2



Eccentric under-reamer system

4 DUAL ROTARY DRILLING (DR DRILLING)

4.1 Concept

The distinguishing feature of the Dual Rotary rig is a lower rotary drive which is used to independently advance casing up to 40" (1016 mm), depending on the drill model.

The lower drive transmits pulldown, pullback and rotational forces to the casing. A carbide studded shoe, welded to the bottom casing joint, cuts through the overburden.

Figure 3

Manual representation of the forces at work when Dual Rotary Drilling, including pulldown and rotation for both the drill string and casing

Figure 4

Cuttings are typically evacuated using air from the on-board compressor. The DR can also be setup for mud or reverse-flooded applications. Note how the cuttings are diverted through the discharge swivel. A longer discharge hose can be added to direct cuttings to a designated dumping point, container, or optional sampling cyclone.

The rotary top drive has its own feed system and raises and lowers independently of the lower drive. The rotary top drive handles the inner drill string, which can be tooled with a down-hole hammer, drag bit, or rolling cone bit. Cuttings are typically removed using air from either the on-board compressor or an auxiliary compressor. Because the top drive and lower drive operate independently of one another, the drill bit can be positioned ahead or behind the casing shoe. For example, the casing can be advanced ahead of the drill bit, minimizing aquifer cross contamination and loss circulation and eliminating borehole stability problems associated with artesian conditions. In typical drilling operations, the drill bit is advanced slightly ahead of the casing for fastest penetration rates. It is worth noting that once the casing is chucked in the lower drive it can be rotated either clockwise or counter clockwise.

Once the casing has been set to the required depth, the DR drill can continue to drill open hole in the same manner as a conventional top drive air drill without tripping out to change the bit.

Figure 5

Lower drive feeds on two directly connected hydraulic cylinders (outside left & right). The top-drive feeds on a separate cylinder (center).

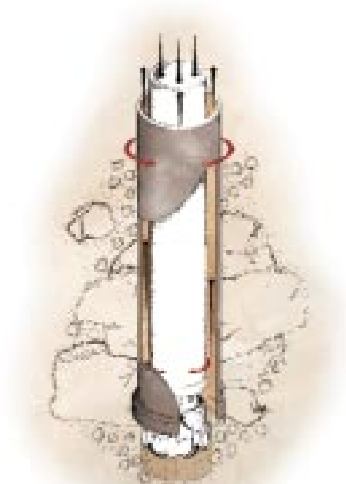


Figure 6

Normal drilling position - the drill bit is advanced flush with or slightly ahead of the casing bottom.

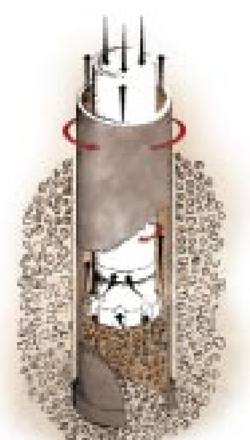
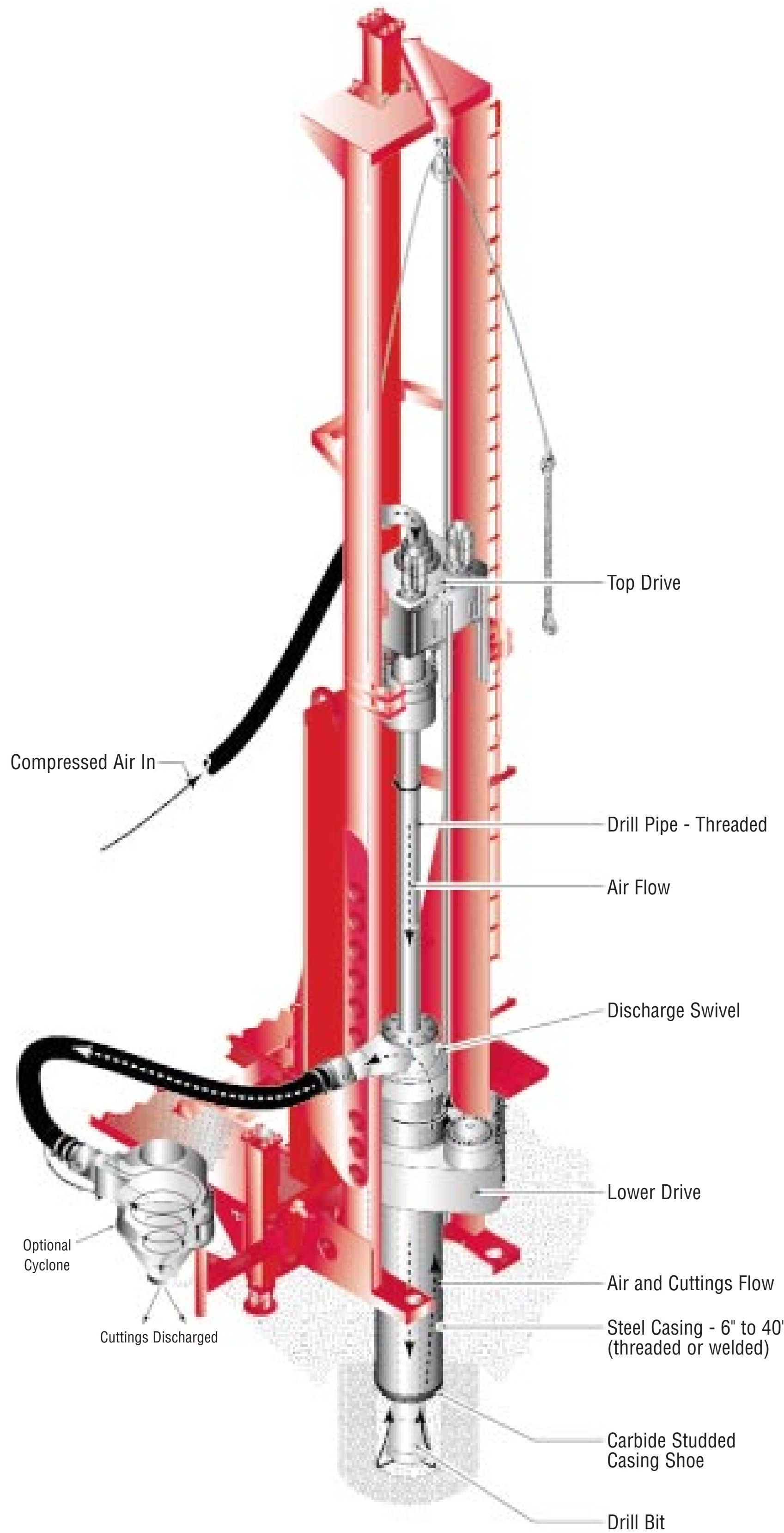


Figure 7

In heaving formations, the casing can be advanced ahead of the drill bit to create a plug.

Figure 8

Overview of key Dual Rotary drill components. The separation cyclone is available as an option.



4.2 Available Models

Today, a variety of Dual Rotary rig models are available, including the DR-12, the DR-24, DR-24HD and the DR-40. The DR nomenclature is straightforward. The 'DR' stands for 'Dual Rotary'. The number indicates the maximum casing diameter, in inches, that a particular model can handle through the lower drive spindle. For example, a DR-24 is a Dual Rotary rig that can handle a maximum diameter casing of 24" (610 mm). The DR-24HD is a heavy-duty version of the DR-24 that offers increased lower drive torque and pullback capacity. Each model offers different feed and torque ratings as follows:

	DR-12	DR-24	DR-24HD	DR-40
Primary Application	domestic waterwell	domestic & municipal waterwells and construction	deep waterwell, mine de-watering and utility shafts	large diameter municipal wells and construction
Top Drive Pullback	37,600 lbs 17 000 kgs	58,000 lbs 26 300 kgs	84,000 lbs 38 000 kgs	84,000 lbs 38 000 kgs
Top Drive Torque	9,700 lbs.ft 13 100 Nm	12,500 lbs.ft 17 150 Nm	12,500 lbs.ft 17 150 Nm	22,000 lbs.ft 30 000 Nm
Lower Drive Pullback	42,400 lbs 19 200 kgs	72,000 lbs 33 000 kgs	117,000 lbs 53 000 kgs	75,000 lbs 34 100 kgs
Lower Drive Pulldown	18,800 lbs 8 500 kgs	33,000 lbs 15 000 kgs	42,000 lbs 19 000 kgs	33,000 lbs 15 000 kgs
Lower Drive Torque	42,000 lbs.ft 56 500 Nm	83,000 lbs.ft 112 000 Nm	208,000 lbs.ft 282 000 Nm	288,000 lbs.ft 390 475 Nm
Drill Power Source	PTO	PTO or Deck Engine	PTO or Deck Engine	Deck Engine
On-Board Air - PTO from Carrier (cfm@psi or l/s@bar)	900/350 424/24.1	900/350 424/24.1	900/350 424/24.1	N/A
On-Board Air - 600 hp (447 kW) deck engine (cfm@psi or l/s@bar)	N/A	1150/350 543/24.1	1150/350 543/24.1	1150/350 543/24.1
Total GVW	47,000 - 51,500 lbs 21 350 - 23 400 kgs	56,000 - 72,000 lbs 25 400 - 32 650 kgs	68,000 - 84,000 lbs 31 000 - 38 200 kgs	105,000 lbs 47 600 kgs

4.3 Features

All Dual Rotary drill models share a number of unique design features.

4.3.1 *Hydraulic Feed System*

Both the top and lower drive units are raised and lowered via directly connected hydraulic cylinders. Benefits of this design include a high pullback to weight ratio, zero load on the mast's crown, and the elimination of cables, chains, sheaves and sprockets in the feed system for reduced maintenance.

Figure 9

The lower drive is also used as a powerful breakout wrench.

Figure 10

Standard tilting top-drive enables safe handling of drill pipe and casing.

Figure 11

DR-12 with optional pipe tub and single rod loader in domestic waterwell application

4.3.2 *Breakout Using Lower Drive*

In addition to providing the feed and rotation needed to advance casing, the powerful lower drive is used to make and break tool joints, hammers and bits *(see figure 9)*.

4.3.3 *Tilt-Out Top Drive*

The top drive, designed and manufactured by Foremost, has a hydraulic tilt-out feature that enables safe and efficient loading and unloading of drill pipe and casing *(see figure 10)*. DR-12 models are also available with an optional pipe tub and single rod loader *(see figure 11)*.

4.3.4 *Cuttings Discharge Swivel*

All cuttings that rise up the annulus between the drill pipe and casing are diverted through a discharge swivel which attaches to the top of the casing *(see figure 12)*. An integral bearing, protected by patented hard metal seals provides support between the rotating casing and stationary discharge elbow. A cone seal prevents cuttings from blowing by as the drill pipe rotates. Cuttings are directed by a flexible hose to a convenient dumping point or optional sampling cyclone *(see figure 15)*.

Figure 12

Standard discharge swivel sizes are 10'' (254 mm), 16'' (406 mm) and 24'' (610 mm) and can accommodate 3 1/2'' (89 mm) to 18'' (457 mm) diameter drill pipe. Discharge swivel adapters allow the swivel to be fitted to other casing sizes.

4.3.5 *Casing Shoe*

A carbide-studded shoe, welded onto the casing, cuts through boulders and hard formations as the casing rotates. This shoe also enables the Dual Rotary drill to seat casing into bedrock. It is important to note that

4.3.5 *Casing Shoe* [CONTINUED]

casing shoes used with the DR have the same inside diameter as the casing I.D. Consequently, there is no reduction in the borehole diameter when switching to open hole drilling. The outside diameter of the casing shoe is fractionally larger than the casing O.D. for reduced friction on the outer wall of the casing. Casing shoes are available in light duty, standard duty, and heavy duty and are distinguished by the spacing of the carbide buttons *(see figure 13)*.

4.3.6 *Casing Jaws*

The lower rotary drive engages the casing via a set of three power-activated casing jaws. Once the casing is locked in the jaws it can be rotated clockwise or counter-clockwise while simultaneously applying pulldown or pullback. The hardened steel jaws are available for all common casing sizes and feature replaceable pipe tong inserts. The lower drive design enables the jaws to be changed out quickly in the field *(see figure 14)*.

Figure 13

A carbide-studded casing shoe is welded to the bottom of the first casing joint.

Figure 14

Casing jaws

5 DR ADVANTAGES AND PERFORMANCE IN OVERBURDEN CONDITIONS

The Dual Rotary method provides several advantages that deliver economic benefits to the drilling contractor over traditional overburden drilling systems.

5.1 Depth Ranges with Dual Rotary Method

On any Dual Rotary rig, the maximum diameter of the casing is equal to the spindle diameter of the lower drive. On some projects, drillers have used adapters in the lower drive to set surface casing that is larger than the lower drive would normally allow.

The table below is based on DR operator experience, drilling in a variety of formations in different parts of the world. It highlights the capacity of the rig to advance casing in difficult formations to significant depths. These figures are guidelines only. Obviously, local drilling conditions will dictate the relationship between casing diameter and depth.

Casing Diameter		Depth Range	
6" - 8"	152 - 203 mm	500 - 1300 ft	152 - 400 m
10" -14"	254 - 356 mm	300 - 800 ft	91 - 244 m
16" - 24"	406 - 610 mm	100 - 500 ft	30 - 152 m
26" - 40"	660 - 1016 mm	100 - 350 ft	30 - 106 m
> 40"	> 1016 mm	For surface casing only	

5.2 Penetration Rates

The table below, prepared by an independent third party, compares penetration rates using a variety of drilling methods.

	Foremost Dual Rotary	Conventional Air Rotary	Auger	Cable Tool
Drilling Speed *(1)*				
Sand and Gravel	20 - 40 min	45 - 90 min	30 - 60 min	1 - 4 hrs
Till	30 - 60 min	45 - 90 min	30 - 120 min	2 - 8 hrs
Rock	30 - 90 min	30 - 90 min	N/A	N/A
Casing Integrity	Excellent	Moderate - Poor	N/A	Moderate
Split Spoon Sampling Ability	Moderate - Poor	Poor - None *(3)*	Excellent	Good
Cross-Contamination Prevention	Good - Excellent	Moderate - Poor	Moderate - Poor	Moderate - Poor
Versatility	Excellent	Good *(3)*	Moderate - Excellent	Poor
Air	Yes	Yes	*(3)*	No
Mud	Yes	Yes	*(3)*	*(3)*
Water	Yes	*(3)*	*(3)*	Yes
Other Advantages/Disadvantages	- Casing removal simplified	- Poor casing seat by juttering and drive shoe removal	- Mobile rig for tough access	- Rig simplicity
	-Powerful			
	- Controlled discharge sampling			
	- Good casing seat in bedrock			

(1) Drilling speed shown represents average time required to drill and install 20 feet over a 100 foot well depth.
(2) N/A denotes Not Applicable
(3) Rig type dependent

5.3 Boulders

The carbide-studded casing shoe enables the casing to be rotated through boulders without the need for under-reaming or blasting. As casing deflection is minimized, the hole remains plumb.

5.4 Heaving Formations

Where heaving ground conditions are experienced, the bit can be retracted into the casing creating a “plug” in the casing which allows drilling to proceed under controlled conditions in most situations.

5.5 Installing and Welding Casing

The operation of installing and welding lengths of casing together is simplified with the Dual Rotary rig. The tilting top drive allows drill pipe and casing to be added and secured to the discharge swivel with the operator standing safely at ground level.

Once secure, the top drive is raised, and the drill pipe and casing are returned to the vertical position. The top drive is rotated to thread the drill pipe into the downhole string and then the holdback wrench is removed. Next, the top drive is lowered until the two casings are lined up and then they are temporarily tack welded in place. Now, with the downhole casing held firmly in the lower drive, the main welding operation begins. As welding progresses, the welder can periodically rotate the lower drive enough to keep his work in front of him. With the DR method, the welder never has to climb in behind the table to complete the weld.

5.6 Setting Screens

The lower drive is equally effective at extracting casing, simplifying the process of setting and exposing screens.

5.7 Sampling

The Dual Rotary drilling method, employed in conjunction with a cyclone collection system, ensures an accurate sample of the formation being drilled. When the casing is advanced simultaneously with the drill bit, the cuttings that return to the cyclone do not mix with material from the borehole wall and are therefore representative of the substance at the bit face. Furthermore, in lieu of welding, threaded casing can be used with the DR rig for monitoring and sampling applications.

Figure 15

DR-12 shown with optional cyclone collection system.

5.8 Angle Drilling

An optional angle package enables drilling and/or casing at angles up to 45 degrees *(see figure 16)*. Even shallower angles have been drilled in some special applications, such as the installation of a utility shaft under a highway at 21 degrees off horizontal.

5.9 Hole Straightness

A key benefit of casing rotation is a straight hole, even when drilling in cobbles and boulders. A straight hole helps to minimize sidewall friction, reduce stress on casing joints and welds and enable greater casing depths.

5.10 General Versatility

In most situations, all that is required when drilling with a Dual Rotary rig is a conventional drill string, casing and a casing shoe. However, a DR rig is versatile such that it can use a variety of common tools available on the market for specialized jobs or unique situations. Reverse Circulation (RC) systems are widely used by owners in both airlift and reverse water flooded applications. Mud drilling is also possible, as is under-reaming.

Figure 16

Foremost DR-24 drilling and casing at 45-degree angle

6 DUAL ROTARY APPLICATIONS

Essentially developed as a water well rig, this unique drill has evolved to a point where it is used routinely with great success in a variety of applications. In addition to applications that involve setting or extracting casing, the Dual Rotary rig can be used as a conventional top-drive drill with the added convenience of a tilting top drive.

6.1 Waterwell Applications

6.1.1 *Domestic Waterwell*

The DR-12 model was designed specifically for domestic waterwell applications. One DR-12 operator was observed to drill a 6" (152 mm) cased hole to a depth of 580 ft (180 m) in sand and gravel, with ample torque and pullback available to advance casing even deeper. DR-12 models are available with an optional pipe tub and single rod loader for open-hole applications. DR-24 models are also often used for drilling domestic wells with operators reporting depths exceeding 1300 ft (400 m).

6.1.2 *Municipal and Agricultural Waterwell*

DR-24, DR-24HD and DR-40 rigs have all been used to drill large diameter industrial wells to varying depths. For contractors using the Dual Rotary method, the predictability of penetration rates in known formations translates into accurate project cost estimates, which provide a distinct advantage when responding to competitive bid invitations.

Some municipalities are specifying the Dual Rotary method for drilling their wells to eliminate mud contamination. Mud disposal costs are increasing and some landfills no longer accept used mud.

6.1.3 *Well Abandonment and Casing Recovery*

As the lower rotary drive is equally effective at retracting casing, the Dual Rotary rig is highly suitable for well abandonment and casing recovery projects. Furthermore, the lower drive and casing can be used to over drill in order to rescue lost tools.

Figure 17

DR mast mounted on crane leads to set foundation for retaining wall

6.2 Construction Applications

6.2.1 *General Building Foundation Construction*

Truck, track, trailer or crane mounting options make the DR flexible for numerous job sites. The DR's angle drilling capability is often a crucial advantage in construction applications. Plus, the DR's ability to control cuttings ensures a clean drill site.

6.2.2 *Hydraulic Elevator Shaft Drilling*

Independent rotary drives produce straight holes, which are essential for this application.

6.2.3 *Dock/Wharf Construction*

DR rigs excel in heaving, water-bearing formations where the potential for hole collapse exists. Angle drilling capability allows for effective drilling of batters. The DR is also able to drill through industrial debris, such as steel and wood, commonly found on dock construction and rehabilitation projects.

6.2.4 *Bridge Supports*

The DR can penetrate where pile hammers and augers fail, which is especially important when bridge supports must be drilled beyond the overburden and seated into the bedrock.

6.2.5 *Land Reclamation Projects*

The DR can drill through the large boulders and industrial debris often found on land reclamation projects. The technology allows a hole to be drilled and cased through these difficult formations without significant bending or deflection.

6.2.6 *Dam Construction And Rehabilitation*

DR rigs offer the dual purpose ability to de-water and set dam foundation anchors. For dam rehabilitation projects, the DR is ideal for drilling grout injection holes. In circumstances like this, where the structure is already cracked or fractured, the casing is advanced ahead of the bit to minimize the chance of blowout. Also, the rotation of the casing minimizes the potential for vibration damage to the already fragile structure.

Figure 18

Above - DR-24 working from barge

Below - DR-40 drilling rock-socketed holes for grouted H-beams on wharf construction

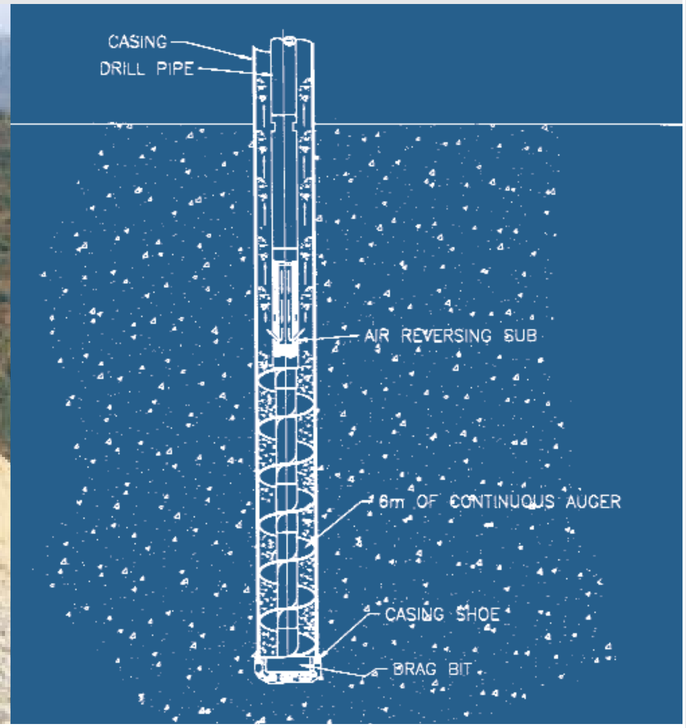
6.2.7 *Tie-Back Holes*

The DR does not have the positioning flexibility of a dedicated tie-back rig, however, for larger diameter, high risk tie-back holes, the DR is a good option. For these jobs, casing can be set to guide the placement of the steel wire. Then, just as easily, the DR can extract the casing while grout is injected into the hole.

6.2.8 *Rock Sockets*

The DR can seat casing into bedrock without fracturing the surrounding formation. The independent top-drive allows the drill string to advance ahead of the casing to create a deep rock socket.

Figure 19



Foremost DR-24 working at dam site. Because of concern over blowout potential, an air-reversing sub was positioned 6m (18ft) above the drill bit to divert air flow back up the annulus to clear cuttings from the auger string. The tooling configuration created a low-pressure vacuum at the bit, eliminating the possibility of a blowout.

6.2.9 *Seismic Retrofitting*

DR rigs offer the accuracy to re-drill existing pilings combined with ability to set sockets deep into bedrock. For example, a Foremost Dual Rotary rig was used successfully for a seismic retrofitting project on the Benecia-Martinez Bridge in the San Francisco Bay Area of California. The project design required drilling 17" (432 mm) diameter casing through existing steel-reinforced foundation shafts.

6.2.10 *Drilling In Populated Urban Areas*

Drilling accuracy, the ability to advance casing without percussion, and control of cuttings discharge make the DR drill and excellent choice for drilling in populated urban areas or near sensitive or precarious structures.

6.3 Mining and Exploration Applications

6.3.1 *Underground Mine Utility Shafts and Mine Abandonment*

DR rigs offer proven drilling accuracy. This fact, combined with angle drilling capability, makes the DR well suited to drilling mine utility shafts or locating and backfilling abandoned sections of underground mines.

6.3.2 *Placer Drilling*

For this application the casing is advanced ahead of the drill bit to preserve the accuracy of cuttings sample *(independent study available, contact Foremost for a copy)*.

6.3.3 *Mine and Construction Site De-Watering*

Dewatering wells can be drilled through loose overburden material including blasted rock and industrial debris.

6.4 Environmental Applications

Whether the goal is to contain environmentally hazardous cuttings, obtain an accurate profile of the formation or just keep a clean job site, the DR method is ideal.

6.4.1 *Environmental Sampling*

As in placer drilling, casing can be advanced ahead of the drill string so cuttings do not mix with material from the borehole wall as they exit the hole. Cuttings remain representative of the material at the bit face. In recent years, some US Government authorities have specified the DR method for a growing number of projects because it is possible to drill and case without introducing water or mud into the formation. On critical environmental sites, a DR can install casing and retrieve cuttings into containers without releasing water or unfiltered air into the atmosphere. The DR can also be fitted with Reverse Circulation (RC) hammers and tooling, which can be beneficial when drilling in contaminated soils, or when sampling in open-hole applications.

6.4.2 *Monitoring Wells*

The ability to case a hole with minimum cross-contamination makes the Dual Rotary method well suited to environmentally sensitive drilling projects. On some projects, it has been recommended as the only acceptable method.

6.4.3 *Re-Charge Wells*

The DR effectively uses casing to seal off the strata above the recharge reservoir. This prevents undesirable material or substances such as salt from bleeding further down into the formation and causing cross-contamination. And, because drilling is accomplished without the use of drilling mud, there is no danger of plugging or contaminating the underground reservoir.

6.5 Other Applications

6.5.1 *Cathodic Protection*

DR rigs offer an advantage when anodes must be buried in overburden or when casing is being set to house the sacrificial anode.

6.5.2 *Hollow Stem Auger Drilling*

For special limited applications, hollow stem augers can be fitted to the lower rotary drive using an optional adapter.

6.5.3 *Kelly Driving*

The torque of the lower drive can be added, via kelly bar, to the torque of the top drive to enable large diameter open-hole drilling. This is useful where the required borehole diameter exceeds the I.D. capacity of the lower drive spindle or when the torque requirements exceed the output of the top drive. Cuttings are typically evacuated using reverse flooding in this application *(see figure 20).*

Figure 20

Dual Rotary rig in kelly bar drilling application.

6.5.4 *Oilfield Rat Hole Drilling*

The Dual Rotary Method is being used in Western Canada by oilfield service companies to drill rat holes, mouse holes, and conductor casing for oil and gas wells. In oilfield applications, a 20" (508 mm) conductor casing is externally cemented into a 24" (610 mm) borehole to depths of 300 ft. (100 m), or more. In some cases, the DR method is also being used to pre-set Range II surface casing.

7 SUMMARY

Since its introduction the Dual Rotary drilling method has gained worldwide acceptance as a cost-effective drilling technique. It has proven to be a viable alternative to more conventional methods when drilling in unstable overburden. Its flexibility and versatility continues to deliver economic advantage to drilling contractors. Without question, the Dual Rotary concept has contributed significantly to advancing the technology of overburden drilling.

For further information about the Dual Rotary drilling method and Foremost Dual Rotary rigs, including brochures, application videos, case studies and drill quotations, please contact Foremost Industries at:

Foremost Industries, LP
1225 - 64th Avenue NE, Calgary, Alberta, Canada T2E 8P9
Tel: 403-295-5800 • Fax: 403-295-5810 • 1-800-661-9190 Canada/U.S.A.
E-mail: sales@foremost.ca • Website: www.foremost.ca

Foremost Industries, LP
1225 - 64th Avenue NE, Calgary, Alberta, Canada T2E 8P9
Tel: 403-295-5800 • Fax: 403-295-5810 • **1-800-661-9190 Canada/U.S.A.**
E-mail: sales@foremost.ca • Website: **www.foremost.ca**

Printed in CANADA