CASING WHILE DRILLING: A TECHNO ECONOMIC OVERVIEW

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ABSTRACT

The Casing Drilling System (CDS), a concept to drill a well using casing as a drill string. This means here casing is used to completely eliminate the use of conventional drill pipe. After drilling up to required depth, the well is cased using the same casing. This will reduce overall drilling time and hence well cost. In this system, casing serves as the hydraulic conduit and means of transmitting mechanical energy to the bit. A short wire line retrievable bottom hole assembly (BHA) consisting of at least a bit and expandable under reamer are used for casing drilling apart from casing pipes. The casing transfers hydraulic and mechanical energy to a wire line-retrievable drilling assembly suspended in a profile nipple located near the bottom of the casing. A drill lock assembly (DLA) in the top of the drilling assembly provides mechanical (axial and torsion) coupling and hydraulic seals to the casing. It also provides a mechanism to facilitate insertion and retrieval from the casing string. The drilling assembly below the DLA terminates in a pilot bit but may include other conventional drill string components, such as an under reamer, a mud motor, coring, or a directional assembly.

One of the most meaningful benefits of casing drilling is the reduction of down hole trouble time. By concurrently casing while drilling, lost circulation and well control incidents have been nearly eliminated thereby enhancing safety. This is particularly key for wells that encounter a weak zone prior to drilling into a higher-pressure zone.

This project on casing drilling system focuses on nearly all important aspects of drilling wells using this technology. The objective of the project is to study and analyze casing drilling system which has been primarily designed for multi-well offshore platforms, multi well operations on land, deep-water operations, and for situations requiring operators to drill through and place casing across problem formations quickly.

In this project we have done literature survey on casing while drilling and have focused on the practical and technical aspects of casing while drilling technology, its advantages and global technical development. We have shown some case studies from published literature which reflects the benefits of the casing while drilling technology.

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ABBREVIATIONS

ABC Suite	: Analysis Behind Casing Suite
BHA	: Bottom Hole Assembly
BOP	: Blowout Preventer
BP	: British Petroleum
BRT	: Bit Release Tool
CDS	: Casing Drive System
CPN	: Casing Profile Nipple
CWD	: Casing While Drilling
DLA	: Drill Lock Assembly
DWL	: Drilling With Liner
E&P	: Exploration and Production
ECD	: Equivalent Circulation Density
GPM	: Gallons per Minute
HHSI	: Hydraulic Horsepower per Square Inch
IADC	: International Association of Drilling Contractors
ID	: Inner Diameter
LWD	: Logging While Drilling
MLT	: Multi-lobe Torque Ring
MP	: Managed Pressure
MWD	: Measurement While Drilling
NCR	: No Casing Rotation
OD	: Outer Diameter

PDCF	: Pump Down Cement Float
PDM	: Positive Displacement Motor
PLC	: Programmable Logic Controller
PPG	: Pounds per Gallon
ROP	: Rate of Penetration
RPM	: Revolutions per Minute
RST	: Rotary Steerable Tool
TD	: Target Depth
UBD	: Under Balanced Drilling
WOB	: Weight on Bit

1. AN INTRODUCTION TO CWD

1.1. Introduction

Rotary drilling, as we know it today, replaced percussion or cable tool drilling in the 1930's. Since that time, wells have been drilled using a drill string consisting of drill pipe, drill collars, a bit and varying down hole tools known as a "bottom hole assembly" (BHA). When the bit wears out or the BHA has to be changed, the process of "tripping" is commenced. Tripping consists of hoisting the drill siring out of the well in lengths of 30, 60, or 90 feet. This process is labor, equipment and energy intensive and takes up to 35% of the total time to drill a well. In addition to the productive drilling time lost to tripping, unscheduled events during tripping, like kick, reaming, stuck ups etc., can make the drilling process even more inefficient and can even lead to losing the well.

Casing-while-Drilling (CWD) involves integrating the casing running process with the drilling process. The CWD process allows casing strings (or liners) to be installed in a well during the hole making process where all, some parts of, or none of, the drilling tools required can be recovered after the casing reaches the required depth. Since there are a variety of possible configurations for CWD systems, the casing (or liner) may or may not be rotated during the drilling process and the drilling tools may be integrated into the casing string or may be part of an assembly that extends below the casing shoe.

The Casing-While-Drilling concept is not new, but there is obviously renewed interest based on the number of patents granted to E&P operators and service companies during the last twenty years that relate to drilling with casing (full strings or liners). In the 1950's it was a common practice for onshore operators to drill production hole sections to TD with the tubing and then cement it in place (without recovering the bit) and this practice is still thriving.

During the last ten years, the industry flirted with, and then abandoned, slim-hole continuous coring (from the mining industry) for low cost exploration. Time was saved, as the drill rods were sized to be cemented as casing, without pulling the coring bit. The next smaller size of drill rod was then used to drill out. Hence, the slim-hole mining systems

have evolved into the first commercial CWD systems. In the last five years Mobil and BP Amoco have taken advantage of the incremental developments in CWD liner technology and further refined them to drill across pressure transitions into severely depleted reservoirs.

This paper will describe the physical components and operational aspects of the casing drilling system and its benefits over conventional drilling system. The anticipated results of drilling with casing are discussed and specific conclusions include up to 30% savings in well costs feasible through drilling with casing.

1.2. Description

The Casing Drilling System (CDS) provides an alternative to the conventional drilling system by using ordinary casing as the drill-string which remains in the hole at all time. In this system, casing itself serves as the hydraulic conduit and means of transmitting mechanical energy to the bit. Thus the well is cased as it is drilled which may reduce well costs or enable problematic hole sections to be drilled. A short wire line retrievable bottom hole assembly (BHA), consisting of at least a bit and expandable under reamer, are used for casing drilling along with casing pipes. This system allows operators to simultaneously, drill, case, and evaluate oil and gas wells. With casing drilling, the well is drilled with standard oilfield drill bits and other down hole tools are lowered via wire line through the casing and latched to the last joint (bottom most) of casing.

The casing transfers hydraulic and mechanical energy to a wire line-retrievable drilling assembly suspended in a profile nipple located near the bottom of the casing. A drill lock assembly (DLA) in the top of the drilling assembly provides mechanical (axial and torsional) coupling and hydraulic seals to the casing. It also provides a mechanism to facilitate insertion and retrieval from the casing string. The drilling assembly below the DLA terminates in a pilot bit but may include other conventional drill string components, such as an under reamer, a mud motor, coring, or a directional assembly.

In most casing drilling applications, an under reamer is used above a pilot bit to open the hole from the pilot-bit diameter to the final well bore diameter. The pilot bit is sized to pass through the casing, and the under reamer opens the hole to the size that is normally drilled

to run casing. The casing drilling system uses a top drive to rotate the casing. Single joints of casing are picked up off the pipe rack and set in the mouse hole. The top drive, with an extend feature, is connected to the top of the joint, which is then stabbed into the top of the casing string in the rotary table. The casing joint is drilled down by using the top drive in a conventional manner. The casing string is rotated for all operations except slide drilling with a motor and bent housing assembly for oriented directional work.

Casing drilling permits operators to simultaneously drill case and evaluate oil and gas wells, thereby significantly reducing drilling time and the potential for unscheduled events. One of the most meaningful benefits of casing drilling is the reduction of down-hole trouble time. By concurrently casing while drilling, lost circulation and well control incidents have been nearly eliminated thereby enhancing safety. This is particularly key for wells that encounter a weak zone prior to drilling into a higher-pressure zone.

1.3. Area of Application

- Swelling formations
- Sloughing formations
- Washout
- Swab oil & gas
- Hole in casing or key seat
- Running logs & casing difficulties

1.4. Advantages & Features of Casing while Drilling

- Well bore integrity is preserve
- Elimination of Drill pipe, Heavy Weight Pipe and less bottom hole assembly to make a complete Well. Also its cost, transportation, maintenance and inspection.
- No tripping and other pipe-handling means reduced manpower requirements and related safety incidents
- Less horsepower required means lower maintenance, lower fuel costs
- Increased bit hydraulics due to smaller annular clearance
- Lighter weight substructure and derrick reduce capital and logistic costs (no setback, lower wind load ratings)

- Lower mud and cementing costs due to smaller well bore diameters
- Documented time and cost savings
- Less chances of mud loss even in weak formations due to smearing effect
- Volume reduction for Drilling mud, completion fluids and cement slurry
- Less drilling time and less completion time therefore less drilling cost
- Reduces or eliminates drill pipe or wire line trip times
- Gets casing to design depth through problem formations
- Reduces the initial surface casing size, because it can go deeper
- Drills straighter holes reducing torque, drag and cleaning problems due to spiraling
- Reduces open hole exposure time and associated drilling problems
- Reduces borehole exposure to formation and completion damage
- Reduces or eliminates well control issues of DP tripping
- Simplifies well architecture
- Optimizes reservoir production

1.5. Types of Technology Available

There are two basic technologies used for Casing Drilling.

- The first technology employed by **Tesco,** uses a bottom-hole assembly comprised of a positive displacement motor (PDM), drill bit and hole opener / under reamer. The assembly is latched to the first joint of casing. As the assembly drills ahead, the casing is lowered into the hole, either in a static or rotated mode. The casing connections are normal buttress thread with Multi torque rings for additional torque resistance. Upon reaching total depth (TD), the latch-on bottom-hole assembly is recovered with a special retrieval tool. A valve system is run and installed before cementing commences.
- The second technology adopted by **Weatherford,** utilizes only casing to transmit rotary torque and weight to the drill bit. A drillable drill bit and valve assembly is made up and run with the first joint of casing. The casing string is rotated during drilling, typically with a spear assembly that provides rotation to the casing. Upon reaching TD, the casing can be cemented immediately, with no need for an additional trip.

2. DRILLING SYSTEMS

2.1. Technology

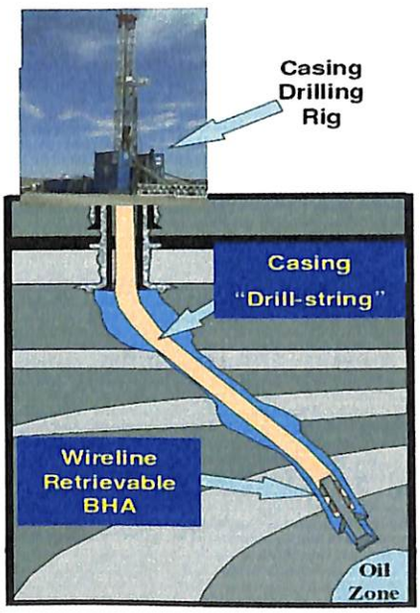
Casing while drilling is the process to drill and simultaneously case wells by using the casing as the drill string. Casing is rotated to drill, and provides hydraulic and mechanical force to the cutting structure. The significant points of this process are:

- Cases the well as it is drilled
- Casing is near bottom at all times
- Casing is cemented in the well without tripping it out

Casing drilling conventionally is done through two different processes:

- Casing drilling with retrievable assemblies
- Casing drilling with non retrievable assemblies.

Figure 1-A Typical CWD System



2.2. Casing Drilling with Retrievable Assemblies-Tesco System

The technology uses unique rig and down-hole equipment that functions as an integrated drilling system. Standard oil field casing is used to transmit mechanical and hydraulic energy to the drill bit. A wire line retrievable drilling assembly that is latched into the casing eliminates the need for tripping with a conventional drill-string.

This system uses a bottom-hole assembly comprised of a positive displacement motor (PDM), drill bit and hole opener / under reamer. The assembly is latched to the first joint of casing. As the assembly drills ahead, the casing is lowered into the hole, either in a static or rotated mode. The casing connections are normal buttress thread with Multi torque rings for additional torque resistance. Upon reaching total depth (TD), the latch-on bottom-hole assembly is recovered with a special retrieval tool. A valve system is run and installed before cementing commences.

The retrieval system is used as:

- Multiple Bit Runs Required
- Lithology changes
- Directional Control Required
    - Number of directional wells increasing on land and offshore
- Trips Required for Logging, Coring, change BHA, etc.

2.3. Components of Tesco System

We have already seen that casing while drilling system differs completely from the conventional drilling system, which includes non rotating casings. It may require some additional equipments apart form the ordinary drilling equipments. The various components of casing while drilling system by Tesco Drilling Technology are:

2.3.1. Surface Equipments

- Top drive system-it is specifically designed to accommodate the wireline the wireline BOP and the casing drive assembly. The bore through the top drive is larger than normal to facilitate the running and retrieving of the wireline rope socket. The top drive is the only practical method to rotate the casing during drilling operations.
- Casing drive system-it is used to engage and hold the casing during drilling operations. It is composed of an actuator, slips and cup packer.
- Split block- the split blocks, split traveling and split crown block, allows the wireline to be run through the crown and down through the top drive, and then through the casing drive assembly into the casing. This facilitates circulation while conducting wireline operations.
- Wireline winch-the rig includes a wireline winch which is used to retrieve the casing drilling bottom hole assemblies. Controls for the wireline winch are usually operated by the Driller and are mounted in the Driller's cabin.
- Wire-line BOP- a wireline BOP is connected to the top of the top drive. The wireline BOP's primary purpose is to control the well in the event of a well control situation during wireline operations. Another purpose of the preventer is to allow the wireline to be run in and out of the hole while circulating.
- Casing strings.

i. Casing Drilling Rig

Casing drilling can be implemented either with a specially developed drilling rig or by a conventional rig modified for casing drilling. To date, the system has been used only with a rig designed specifically to prove the entire system and to maximize the efficiencies of casing drilling.

Special equipment is needed to handle casing in a drilling mode and to handle the wire line retrievable BHA. A top drive must be used to rotate the casing. In addition, a split crown and split traveling blocks facilitate effective wire line access to the top of the casing through a wire line blowout preventer (BOP).

A large wire line unit is needed that is sufficient to run and pull the BHA efficiently. Pipe-handling tools for the casing are also required.

In addition to the rig requirements mentioned above, these rigs include other features that allow the entire drilling process to be implemented more effectively. The rigs are designed with hydraulic power units for the mud pump, drawworks, top drive, and wire line unit, reducing equipment weight while taking advantage of the company's top-drive design.

All this equipment is operated under computer control through programmable logic controller interfaces that minimize the potential for human operator error, optimize equipment performance, reduce manpower requirements, and facilitate data acquisition.

The wire line unit is installed as an integral part of the rig and is located adjacent to the main drawworks. The hydraulic power and computer control allows the driller to function as the wire line operator from the driller's control room. The hydraulic drive on the drawworks is very similar to that shown for the wire line unit and acts as a brake that allows the drill string to be advanced with the drawworks under power rather than with the power unit disengaged by a clutch.

This facilitates building a robust automatic driller and is the first step in developing an adaptive control system for bit advancement that responds to dynamic conditions related to vibrations, casing/borehole contact, bit/formation interaction, mud -motor loading, and other sources of dynamic instabilities.

The initial commercial applications of the casing drilling technology are anticipated to be applied to relatively low-cost land wells. These wells are drilled rapidly, with frequent rig moves; consequently, the mobilization costs can be high.

The hybrid casing drilling rigs are designed in modular packages that can be moved and rigged-up quickly with the use of standard tractors and oil field pickers. The casing-drilling rig currently under construction is mounted on a trailer and designed with a load distribution so that it can be moved in Canada under almost year-round conditions.

A number of features of the casing-drilling process allow for a lighter rig design. The casing is picked up as single joints from the pipe rack. Thus, it does not need the monkey board, setback area, and heavy derrick associated with a conventional rig.

The shorter and smaller derrick reduces wind load considerations, allowing for the construction of a lighter derrick and substructure. Smaller mud pumps can also be used because larger casing IDs significantly reduce the friction loss, as compared to conventional drill pipe and collars. Furthermore, the larger OD of the casing allows adequate annular velocity to be achieved with lower flow rates than otherwise achieved with drill pipe. The overall result is that the rig:

- Is not as heavy to move
- Requires less capital investment
- Uses less power
- Requires a smaller crew.

Tesco's patented Casing Drilling process could lower drilling time up to 30% and reduce unscheduled drilling events.

Casing Drilling Rig Features

Conventional rigs can be modified to use Casing Drilling Technology or use Casing Drilling rig, specially designed and manufactured by Tesco Corporation, will ensure operating efficiency. Casing Drilling Rigs include:

- Split Crown Block
- Split Traveling Block
- Wire line BOP (integrated into a Top Drive)
- Casing Handling Equipment

To drill with casing, a purpose built rig was constructed. There were four basic changes from a conventional drilling rig.

- The first change was to install a wire line winch capable of running and retrieving the BHA. The wire line included an electric line for future tool actuation. Operation of this wire line winch was integrated into the rig PLC control panel.
- The second change was to install a split traveling block and crown and a top drive in order to facilitate running the wire line down through the casing.

- The third change was to install a wire line BOP and double pack-off above the top drive in order to seal off around the wire line.
- The fourth change was to add pipe-handling tools to handle casing instead of a conventional drill string.

Because larger casing IDs significantly reduce the friction loss, as compared to conventional drill pipe and collars. Furthermore, the larger OD of the casing allows adequate annular velocity to be achieved with lower flow rates than otherwise achieved with drill pipe. The overall result is that the rig casing instead of a conventional drill string.

ii. Casing Drive System

The casing running and drilling technology uses the top drive and a portable Casing Drive System (CDS) as the primary components of the casing running system. The top drive provides the power for applying rotation and Casing Drilling is a trademark of Tesco Corporation, torque to the casing, while the CDS provides the ability to pick up joints of casing from the "V-door" with single joint elevators and then grip the top of the casing so that the top drive can be used to make up the connection.

The CDS supports the full torsional and axial load for running the casing and provides the ability to circulate the well while running casing without picking up any other equipment. This system allows the casing to be washed and reamed to bottom any time tight hole or fill is encountered.

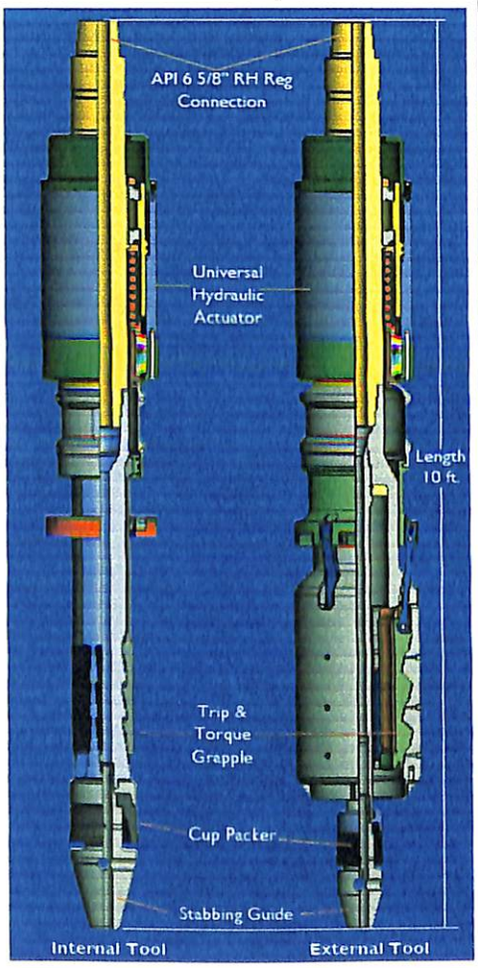
Tesco provides a Casing Drilling system that has been used in over 150 commercial wells to drill more than one million feet with casing since it was, introduced in 1999. While more attention has been focused on the "drilling" aspect of the system, specialized equipment has also been developed to efficiently handle the "casing running" component of the Casing Drilling process.

When drilling with the Casing Drilling system, each joint of casing is picked up with a Casing Drive System (CDS) located below the top drive. This tool supports the full weight of the casing string, applies torque for both make-up and drilling, and facilitates circulation without making a threaded connection to the top of the casing. An operator positioned near the driller controls these functions.

The CDS includes a slip assembly to grip the interior of 9-5/8" and larger casing or the exterior of smaller casing. An internal spear assembly provides a fluid seal to the pipe. This allows the casing to be placed into the drill string without screwing into the top casing coupling. Using the CDS speeds up the casing handling operation and prevents damage to the threads by eliminating one make/break cycle. The CDS is designed so that a common hydraulic actuator can be used to operate both the internal and external gripping assemblies.

Figure shows the two different CDS configurations. It is available in a range of sizes with load and torque ratings that are appropriate for each casing size. The CDS is hydraulically operated with controls that can be positioned anywhere on the rig floor, but are normally located near the driller. The pipe handling hydraulic circuits for the top drive are used to operate the CDS so that no additional lines or controls are needed when it is used with a Tesco top drive. This allows the driller to operate equipment that he is already familiar with and utilizes the pipe-handling safety interlocks that are built into the top drive controls. For non-Tesco top drives, the CDS is powered by a small hydraulic power unit through additional hydraulic lines that are run along the top drive service loop and a separate control stand is placed near the driller. The slip actuator is spring loaded with sufficient force to grip the casing without applying hydraulic pressure. However, hydraulic pressure increases this gripping force when the CDS is engaged and offsets the spring force to release the slips when the CDS is disengaged. In this way, the tool is made to be fail-safe even if the hydraulic pressure is lost while the tool is in use.

Figure 2-Internal and External Casing Drive System



Even though the CDS was originally designed for Casing Drilling applications, it was also found to be ideal for running casing on conventionally drilled wells. Rigging up the CDS entails picking it up and making up the 6-5/8" API Reg

connection to the top drive, installing an anti-rotation bracket and running the control loop. The final step in the rig-up process is to adjust the torque limit on the top drive for the appropriate casing make-up torque. The outer housing of the CDS is suspended on bearings and the anti-rotation bracket must be installed to prevent the housing from turning when the casing is rotated. The bracket attaches to the pipe handler on the top drive, which gives the operator the capability to rotationally orient the link-tilt bails by remotely adjusting the pipe handler position. Installation of this bracket may require some custom fitting the first time the CDS is used on any rig. The casing running process is as follows: The next joint of casing to be run is positioned in either the V-door or the pick-up machine, depending on whether or not a pick-up machine is being used.

As the driller lowers the blocks to run the joint that has just been made up, the operator manipulates the single joint elevator link tilt to position the elevators to catch the new joint of casing in the V-door. He remotely latches the elevators on the new joint from the operator's console. These elevators open wide enough and have sufficient power to latch on the casing even if it is slightly off-center in the V-door. The CDS is released from the stump in the rotary table and the next joint to be run is hoisted as the driller runs the blocks up the derrick. Once the joint is raised sufficiently, the CDS operator rotates the link tilt to swing the new joint of casing over the stump in the rotary table. The joint is stabbed, the CDS is lowered into the top of the joint and the CDS slips are activated. The link tilt and elevators includes features that facilitate holding and positioning the upper end of the casing correctly for the CDS to be stabbed easily and aligning the casing with the stump in the slips. This feature eliminates the need for a human "stabber" and is also more effective than a human. The joint is then made up with the top drive to the appropriate torque. Rotation for the entire process is applied smoothly without needing to stop the rotation. The top drive applies the torque to the casing without creating bending forces at the threads. Torque-turn measurements can be made if required by the operator. Only two people are required to rig up the equipment and operate it during a casing running job. Once the equipment is rigged up, the operators take turns operating the controls so that the operator at the controls is always alert and can pay close attention to the repetitive casing running process.

Picking up and running casing with the conventional method is often an inefficient process, but using the techniques and equipment designed for Casing Drilling makes it both more

efficient and safer. Using the CDS allows casing connections to be made as fast as drill pipe connections, minimizes floor activity while making a connection, and increases rig floor safety. This is particularly true when remotely operated slips are used with the system. Utilizing the new casing running equipment eliminates the need for having people working above the rig floor and provides a much less cluttered floor area. The overall safety of the casing running operation, which has historically been associated with a high accident rate, is improved by eliminating situations where workmen may potentially be injured. Running casing with the new process also allows the casing to be circulated and rotated at any time. This provides the capability to wash through bridges and aids in getting casing run through depleted zones where the potential for differential sticking is high. It is particularly advantageous in running casing in highly deviated wells where the drag is high when run without rotation. The ability to circulate and rotate also helps keep debris from building up and being pushed in front of the casing when it is run in highly deviated wells. As operators gain experience with having the ability to rotate and circulate the casing, it becomes apparent that this capability offers the potential to redesign the hole conditioning procedures that are used to prepare for running casing. Often, time is spent conditioning the mud and making wiper trips before tripping out to run casing. Knowing that the casing can be washed and reamed to bottom makes these activities less necessary and offers the potential to save rig time and mud costs. The ability to rotate the casing also opens the door to improved cementing by rotating the casing as the cement is displaced. Numerous studies have shown that casing rotation improves cement displacement and improves the cement bond. Casing rotation also significantly improves hole cleaning in highly deviated holes, which improves both the ability to run casing and to properly prepare the well for cementing.

The new casing running system takes a completely fresh approach to running casing by utilizing the top drive capability that is provided with the rig and by utilizing the driller and rig crew who are readily available, comfortable with working as a team, and trained in the operator's safety program. This process allows the rig floor to be much less crowded when running casing, eliminates the need to have a stabber in the derrick, reduces the number of people on the floor, and places command of the entire process with the driller who is

positioned in a non-hazardous location. The use of the CDS paves the way for fully automated pipe handling to be employed in the future and in doing so, offers the advantage of no human-to-pipe contact. This capability has been operational on Tesco Rig Gamma for over a year. Using the CDS to run casing as described above is simply the first step to this process and work is under way to make this capability completely portable and compatible (economically and mechanically) with use on less expensive land rigs.

2.3.2. Down-hole Tools

The casing-drilling process eliminates the conventional drill string by using the casing itself as the means of transmitting hydraulic and mechanical energy to the bit. A wire line-retrievable BHA attached to the bottom of the casing, drills a well bore of adequate size to allow the casing to be advanced freely.

The down-hole system has two components:

- Wire-line Retrievable BHA
- Casing Drilling assembly

i. Wireline Retrievable BHA

The BHA is attached to a drill lock that fits into a full bore landing sub on the bottom of the casing in such a way that it can be retrieved with a wire line unit without needing to trip pipe out of the well. The wire line retrievable drill lock assembly is the heart of the casing drilling system. It lands in a lower section of casing consisting of a casing shoe, torque lock profile and axial no-go and lock profile located in a specially machined collar section. The drill lock engages both a fluted profile to transmit rotational torque from the casing to the drilling assembly and an internal flush no-go and axial lock profile to transfer compressive and tensional loads to the BHA. The BHA is attached to the bottom of the casing by a landing assembly so that a wire line unit can be used to retrieve and replace it without needing to trip pipe out of the well.

The BHA consists of a

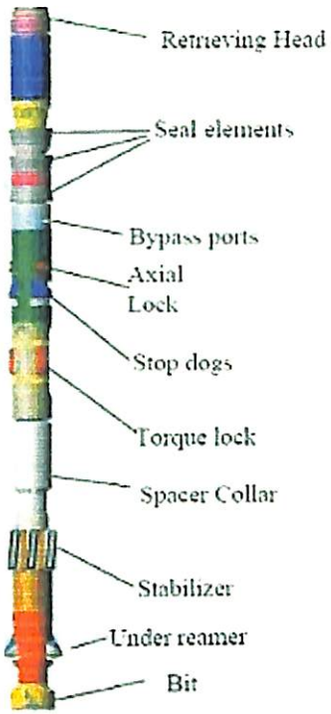
- Running and retrieving tool
- Drill Lock Assembly
- Mud Motors
- Under reamer- that are sized to pass through the "drill-casing".
- Pilot bit -that are sized to pass through the "drill-casing." Thus, it becomes possible to drill a hole while providing adequate clearance for the drill-casing and subsequent cementing.

For directional applications, the BHA includes a bent-housing down-hole motor and measurement-while-drilling (MWD) tool. Other equipment, such as logging-while-drilling (LWD) or coring equipment may also be run to perform almost any operation that can be conducted with a conventional drill string. The BHA is run below a landing assembly to transport it into the well and mate up with a special casing shoe joint. Spring-loaded dogs located on the landing assembly engage a no-go groove on the casing shoe.

This positions the assembly so that positive-locking axial keys extend into a profile to transmit compressive (bit weight) and tensional drilling loads from the drilling assembly to the casing. A torque anchor mates with recesses in the casing shoe to provide rotation and torque transfer from the casing to the BHA.

Seals located on the landing assembly incorporate upward and downward-facing pressure cups that prevent flow around the BHA landing assembly while drilling. A bypass system allows drilling fluid to be circulated, preventing well swabbing and casing sticking when running or retrieving the BHA system allows drilling fluid to be circulated, preventing well swabbing and casing sticking when running or retrieving the BHA.

Figure 3-bottom hole assembly



A stabilizer on the BHA positioned opposite the casing shoe reduces lateral motion of the assembly inside the casing. The casing shoe is normally dressed with hard material to ensure that a full gauge hole is drilled ahead of the casing, but it also provides a torque indication if the under reamer drills under gauge. Centralizers on the casing stabilize it within the borehole and prevent wear on the couplings. The BHA generally consists of a pilot bit and under reamer, but may include other tools needed to perform almost any operation that can be conducted with a conventional drill string. The pilot bit and under reamer pass through the drill casing and drill a hole that provides adequate clearance for the drill-casing and subsequent cementing. Conventional directional tools (bent housing positive displacement motors, MWD tool, and isolation monels and LWD tools can be suspended below the drill casing shoe for directional drilling. Conventional core barrel can be run for coring.

ii. Casing Profile Nipple

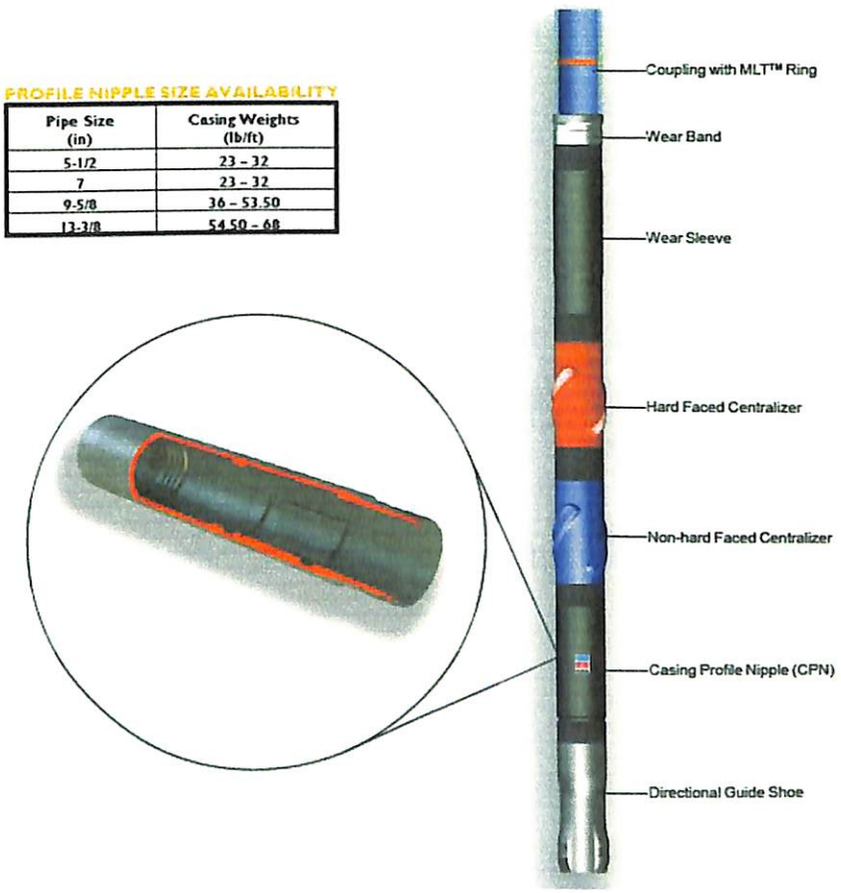
Application & Advantages

- Tesco's Casing Profile Nipple (CPN) is a key foundation component to the patented Casing DrillingTM system. The CPN is installed in the bottom of the casing string and serves as the torsional and axial locking mechanism for Tesco's patented wireline retrievable Drill Lock and Bottom Hole Drilling Assembly (BHA).
- Tesco's CPN is also used as an accessory in conventional Casing RunningTM operations and provides a valuable option for problem well bores where hole conditions may interfere with getting casing to bottom. When installed at the bottom of the casing string, the Casing Profile Nipple provides a contingency to install Tesco's retrievable Drill Lock Assembly, Under-reamer and Bit to drill and ream through the problem areas. Upon reaching TD the drilling assembly is retrieved by wireline.

Figure 4-Casing Profile Nipple

PROFILE NIPPLE SIZE AVAILABILITY

Pipe Size (in)	Casing Weights (lb/ft)
5-1/2	23 – 32
7	23 – 32
9-5/8	36 – 53.50
13-3/8	54.50 – 68



- Tesco's CPN also is compatible with and serves as a landing tool for Tesco's flexibility to both Casing Drilling and Casing Running operations.

Design & Features

- Tesco's Casing Profile Nipple design includes recessed "axial locks" and "torque locks" that mate to the Tesco's wire line retrievable Drill Lock Assembly (DLA) providing the rotational and axial connection for drilling. The positive landing and mating features of the CPN and DLA combination minimizes the need to rely on precise wireline depth measurements.
- The CPN is approximately 3' to 4' long, depending on pipe size, with an outside diameter equal to the API coupling diameter for the respective pipe size.
- The minimum ID of the CPN is equal to or greater than the pipe ID for the specified weight and size of casing. Each CPN is designed to function for several weights of casing in a given pipe size.
- The CPN has the full API performance rating of the casing in Burst, Tension and Collapse. Ends are threaded as required to match the casing string.

2.3.3. Casing Accessories

When the casing is run with the new process that can provide rotation on demand, some accessories may be advantageous. Increasing the torque capacity of the connections and improving centralization

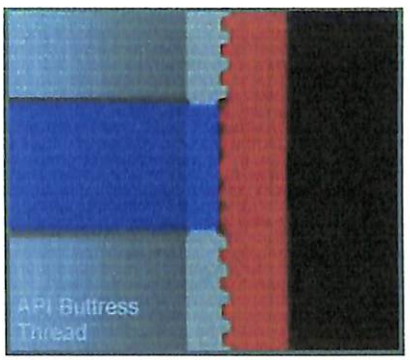
- MLT rings
- Hydro forms centralizers/stabilizers
- Pump Down Cement Float
- Drilling/Guiding Shoe
- Bit Retrievable Tool

i. MLT(Multi-lobe Torque) Rings

Many premium connections have torque shoulders that provide adequate torque for rotating casing, but these connections typically carry a price premium and often require advance planning and ordering. For the common cases where lower cost API connections are used on the casing, the torque capacity may be enhanced with MLT rings. These rings add a significant torque boost (Delta Torque) to API connections for situations where the in-hole

rotation torque may exceed the standard API make-up torque. They are designed for use with standard "off the rack" tubulars common in field inventories Standard API threads develop torque through bearing loads resulting from high radial stresses between the mated pin and coupling.

Figure 5-API Buttress Thread



The application of excessive torque can damage the connection by driving the pin too deeply into the box, decreasing pin ID and increasing pin and coupling stress. The field installable MLT ring fits into the center "J" dimension of API (Round thread or Buttress) couplings to provide a positive stop and shoulder for the pin ends. The addition of the MLT ring creates a shoulder for the pin ends, which provide an added torque capacity, termed "Delta torque".

Figure 6-MLT Rings



API Buttress Thread: The shoulder prevents over penetration of the pin in coupling and the flush ID improves flow performance and keeps debris from the coupling threads, improving connection life through repeated make-break cycles. Buttress threads with MLT rings have higher torque capacity than Round threads with rings, which is one of the reasons why buttress threads with MLT rings are more commonly used when drilling with casing.

MLT™ Rings are color coded to 4 specific lengths to accommodate full API makeup tolerances.

ii. Casing Drilling™ /Running Shoes

Design, Application & Advantages

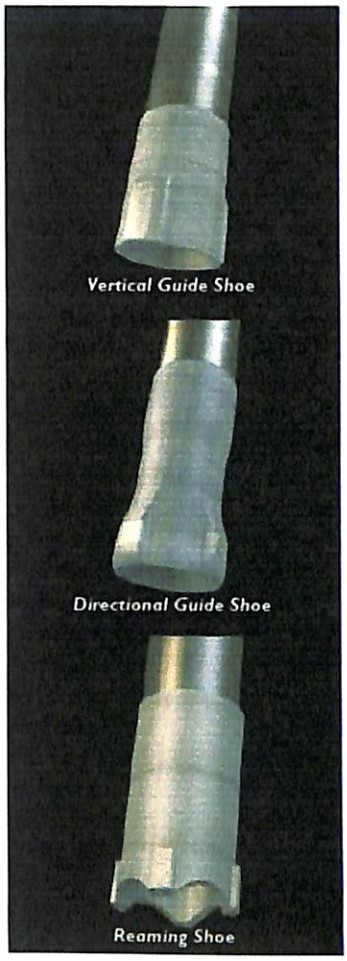
- Tesco's Guide Shoes are applied to the casing shoe joint used with Casing Drilling™ in both vertical and deviated wells. Tesco's Reaming Shoe is used in Casing Running™ applications.
- For Casing Drilling™, Guide Shoes serve the following important functions:

- Guide the casing string into the open hole
- Provide early warning of "under gauge" hole conditions by increasing torque detected at the surface when hole size decreases due to cutting tool wear
- Reinforce the end of the casing and facilitate washing over the BHA (Bottom Hole Assembly) when required

- For Casing Running, Reaming Shoes serve to ream casing to bottom through debris when hole conditions deteriorate.

Shoes for Casing Drilling™ have open ends to facilitate installation and retrieval of the bottom hole drilling assembly with wireline. The ID is matched to the full open bore of the casing ensuring easy tool passage

Figure 7-Guide/Reaming Shoes



iii. Rotating Centralizers

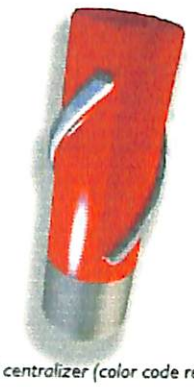
Figure 8-Rotating Centralizers

Centralization for cementing is required on almost every casing string.

Conventional centralizers (typically bow springs) are used when no casing rotation is anticipated. However, when the casing undergoes a significant amount of rotation, conventional bow-spring centralizers are not durable enough, nor is any centralizer held in place by stop collars attached with setscrews. While positive standoff centralizer "subs" can be installed in the casing string, they are quite expensive. Tesco has developed a crimp-on, rotating centralizer with positive standoff and high torque capacity that is effective for applications where the casing will be rotated.



Non-hard faced centralizer (color code blue)



Hard faced centralizer (color code red)

These centralizers feature a one-piece, multi blade design that slides on the casing and is attached with a patented crimping process that hydraulically swages the end of the centralizer onto the OD of the casing. The resulting mechanical interference holds the centralizer firmly in place under both torsional and axial loads without altering the underlying casing properties. Each centralizer is manufactured from a single length of mechanical tube.

The blades are formed on the tube using internal pressure to hydraulically expand ductile tube material into cavities of a mold (hydro-forming). The blades are designed with a right hand spiral helix with the number of blades varying with pipe size. The resulting blades are very durable and can withstand the rigors of extended casing rotation.

iv. Bit Release Tool (BRT)

Application & Advantages

Tesco's Bit Release Tool (BRT) is a multi-purpose tool for Tesco's Casing Driling ® "drill-in" system that utilizes casing as the drill string with the bit attached as a "non-retrievable" Bottom Hole Assembly. The Bit Release Tool serves the following important functions for the casing drill string:

- Crossover – the BRT connects the casing to the bit with API box connections on bottom and casing connections on top.
- Bit Stabilization near the bit – Spiral stabilizer blades maintain directional control of the assembly during drilling.
- Bit Release – the BRT provides a mechanism for removing the bit and lower assembly to open the bottom of the casing.

Figure 9-Bit Release Tool



After "knocking off" the bit, the casing bottom is open to full drift to allow passage of Open Hole Logging tools, generally favored over Cased Hole logging techniques.

The simple yet durable design provides full pressure and torsional integrity during the rigors of drilling while also offering a reliable method of opening the bottom of the casing.

Stabilizer blades for directional control during drilling are hard faced with Tungsten Carbide to withstand abrasive wear.

Design & Features

Release of the bit is achieved by either hydraulic or mechanical force. For the hydraulic option, force is applied by the combination of a ball dropped in the casing and pump pressure applied to "pump off" the bit and lower assembly. "Pump off" occurs when a differential pressure of approximately 900 psi is reached. For the mechanical option, force is applied by wireline tools.

The BRT is an assembly of three basic components:

- The Float Sub is the bottom unit supporting the drill bit and connected to the "bottom sub" with an integral thread. An internal check valve prevents backflow.
- The Bottom Sub receives the dropped ball creating the hydraulic force to separate from the "top sub". Shear screws determines separation at predetermined axial load.
- The Top Sub is stabilized and remains on the casing after the lower assembly is knocked off. The top and bottom subs are designed with castellated ends that provide the torsional lock for drilling.

v. Under reamer

Tesco's Under reamers (UR) were originally designed as a tool for Casing Drilling technology. They have been designed, manufactured and optimized to provide simultaneous under reaming and drilling new hole, while drilling with casing. These tools, available in nominal sizes of 4 1/2" to 13 3/8" to drill 6 1/4" to 17 1/2" have been utilized on over 90 wells over 500,000 feet of hole.



Figure 10-Under Reamer

Benefits

- Integral stabilizer blades
- No bearings, minimal moving parts (1 piston, 3 arms)
- Ease of service and down hole operation
- Design selection of hole size and cutting types
- Ease of hydraulic design selection and information

Applications

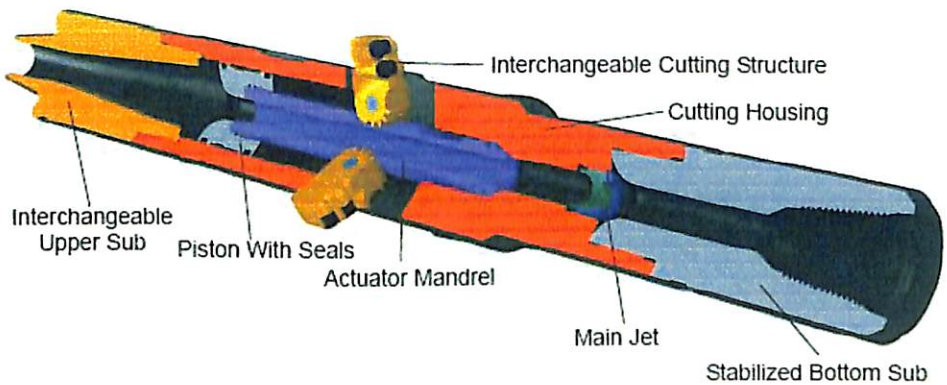
Tesco offers their 5th generation under reamers for under reaming applications on drill pipe or tubing. These applications can include:

- Under reaming below casing to enable gravel packing with slotted liners.
- Obtaining additional annular clearance for oversized or expanded liners.
- Obtaining enhanced drainage radius for increased production.
- Eliminating sloughing or near well-bore damage in older open hole completions.
- Under reaming behind rotary steerable pilot assemblies.

Design of Tesco PDC Under reamer

The key design concept behind the Under reamer is the ability of the Cutter Housing to accommodate three collapsible PDC arms and interchangeable top and bottom subs. This design concept allows the tool to be assembled with a variety of API connections and either box or pins on both the up hole and down-hole ends of the tool. The UR can be assembled with a variety of arm structures in order to accommodate different cutting structures and achieve different hole diameters. Pressure differential causes the Actuator Mandrel/Piston to stroke down and position the arms into a drilling or reaming state.

Figure 11-Design of Tesco PDC Under reamer



Operation of Tesco PDC Under reamer

Preparing to Drill, Opening the Under reamer

- Mud is pumped through the bore of the tool and the interchangeable main jet.
- The mud creates differential pressure between the Actuator Piston Seals and the annulus.
- This differential annular pressure creates force which acts downwards on the Actuator Piston.
- At a pre-determined flow rate, the differential pressure reaches the required magnitude and compresses the spring.
- When this occurs, the Actuator Piston move down within the tool and extends the Cutter Arms. The Under reamer is now in a drilling state.

- Continuous differential pressure ensures that the under reamer remains extended while reaming.

Drilling Complete, Closing the Under reamer

- Mud flow through the tool is stopped completely (or reduced to as low a flow rate as possible if the circulation must be maintained).
- The differential pressure is reduced, causing the spring restoring force to push the Actuator Piston back up inside the tool.
- The Cutter Arms retract.
- The Under reamer is now ready to be retrieved.
- Fail-safe design provides back-up mechanically close at the casing shoe

Options

Tesco offers a number of options to increase the utility of its Under reamer:

- Alternate cutter design and hole size options.
- Shear rings can be installed to hold cutters close to drill out the casing shoe. The Under reamer can then be opened to its full working diameter.
- A jetted mandrel can be installed to clean the cutting structure in soft/sticky formations.
- Rotary steerable tools (RST) and or logging while drilling (LWD) systems can be run in the pilot hole, below the Under reamer.

Availability

Tesco's fifth generation under reamers, proven in Casing Drilling® operations is now available for conventional drilling. Tesco Under reamers are available for sale or lease to qualified operators and service companies. Alternatively, under reamers can be provided on a performance basis.

vi. Design of PDC Cutting Structure

The cutting arm is manufactured from a steel blank, set with premium Polycrystalline Diamond Compact (PDC) cutters. Cutter size and placement is purpose designed for the formations anticipated (soft to medium hardness) and final hole size required.

- Available cutters range in size from 13mm to 19mm in diameter, with a 0.020" chamfer. Back-rake and side rake angles are selected for optimum cutter performance in various formations. For specific applications (eg. abrasive formations, junk, gravel), impregnated diamond, tungsten carbide chips, or other specialized materials may be used in the cutting structure.
- Hard facing is used on the gauge area and front face of the cutter arm to maintain gauge, and resist erosion by the abrasive formations or drilling fluids.
- The "humpback" design of the cutter body provides more gauge-area contact with the drilled hole. This provides for better cutter stability and performance while reaming or back reaming.

vii. Setting and Retrieving Tools

A custom-designed, wire line setting-and-retrieving tool is used to install and remove the BHA. A swivel prevents the rotational twist of the braided wire line so that the casing can be rotated during wire line operations.

An emergency shear sub, activated when line tension reaches 20,000 lb, provides for a straight-pull emergency release of the latch in case tight-hole conditions warrant a disconnect. The design and testing of a pump-down pressure set tool is in progress and an electric retrieving concept is being considered for future application.

viii. Pump Down Cement Float

The Pump Down Cement Float is a cementing accessory for use with Tesco's Casing Drilling® and Casing Running Systems.

Application & Advantages

Tesco's Pump Down Cement Float (PDCF-2) is a composite material cementing tool specifically designed for use with Tesco's Casing Drilling® and Casing Running Systems. The PDCF-2 is a second-generation tool that is simple in design, cost effective and easy to deploy.

The PDCF-2 is deployed by pumping it down the casing from the surface and landing it in Tesco's Casing Profile Nipple (CPN). PDCF-2 can be pumped down at normal pump rates, saving rig time and service costs compared to wireline deployed cement floats.

The PDCF-2 lands and latches in the CPN with a positive stop and self-locking mechanism, providing accurate placement of the float without wireline setting systems.

When landed, an internal check valve holds backpressure, preventing backflow, and the top of the PDCF-2 provides a positive stop for the cementing wiper plug.

2.3.4. Challenges associated with Casing Drilling

Casing drilling involves the use of casing in place of drill pipe. In this process, it proves to be more advantageous than conventional system as it saves time in tripping in and out and thus the process is safer than conventional system but at the same time it has certain challenges associated with it. They can be summarized as follows:

i. Changing the Bit or Bottom Hole Assembly

Conventional rotary drilling rigs use a process called tripping whereby the entire drill string is pulled from the well. This time consuming process can lead to unscheduled events like kick, reaming, stuck ups etc. that further make this process inefficient. Casing Drilling eliminates tripping as we know it and retrieve the down hole tools by wireline through the casing. This will reduce trip time and eliminate the unscheduled events associated with conventional tripping. The down hole tools incorporate both an axial and torsional latching

mechanism to anchor the tools to the bottom of the casing so drilling can proceed by rotation of the casing or the use of a mud motor.

ii. Tubulars and Casing Connections

Normally casing connections are not designed to accommodate high torque and compressive loads in a buckling environment. The casing drilling solution is to drill with relatively low torque, low bit weight and keep buckling to a minimum with reduced hole sizes.

Casing used with retrievable casing system is generally of same size, weight and grade that would normally be used in a well. However the casing connections may require a change because casing in this case has to provide adequate torsional strength, fatigue resistance and flow clearance. To achieve this buttress connections are used with multi-torque rings for additional torque capacity. Both integral and coupled connections have been used successfully.

iii. Drill Bits & Bit Cutting Structure

Drilling with casing and wireline retrieving the tools would require that the cgtting structure be small enough to pass through the inside diameter of the casing, but have the ability to drill a larger hole size than the outside diameter of the casing. This is accomplished by using an under reamer behind a smaller diameter pilot PDC bit.

iv. Centralization and Stabilization

No conventional cementing centralizers were found economical and rugged enough to withstand the drilling forces and that could be attached to the casing without altering its performance. Solid centralizers may need to be added to the casing for directional performance, wear management, key seat control and centralization for cementing. Both the issues have been tackled by installing hydro formed stabilizers and wear bands using crimping process.

v. *Fluid Requirement*

Compared to conventional drilling operations, experience has shown that flow rates can be reduced substantially in "casing drilling system". As annular volume is reduced dramatically, hole cleaning is improved due to higher annular velocities achieved, even with reduced flow rates. Cleaning the hole more efficiently and removing cuttings faster aids in ECD reduction. However, higher annular velocities and the resultant friction losses in the annulus increase the ECD. Each application must be evaluated to determine the balance that must be struck between flow rates to clean the bit face and clear the annulus of cuttings, and ECD management. Once all factors have been considered, the proper flow rate and nozzle configuration can be selected.

An inherent benefit of drilling with casing is the 'mono bore" annulus. Conventional drilling assemblies result in different annular velocities around each drill string component. This can lead to well bore erosion around drill collars and inefficient cutting transport around the smaller diameter drill pipe. With casing as the drill string, the annular space along the entire well bore is virtually equal allowing the optimum hydraulics to be "dialed in" based on the fluid properties, cuttings concentration and flow rate. Hole cleaning ECD management and hole cleaning are much easier. Hole cleaning has not been an issue on previous wells. While no caliper log data is available, lag time and cement returns do not indicate borehole enlargement to be an issue.

vi. *Fishing*

It is possible to conduct conventional fishing operations to recover junk from the hole while Casing Drilling. A fishing operation was conducted using conventional tools junk baskets, magnets, etc). The only difference was that these tools were run in and out of the hole with the wire line, thus making the process faster than having to trip the drill string each time a fishing run was made. The casing may actually be used similar to wash over pipe to assist in the fishing operation.

vii. Logging/Formation Evaluation

Drilling with casing requires that the well be cased as drilling commences. This prohibits logging the open hole with conventional wire-line logging tools once the hole section is complete unless the casing is pulled above the zone and logged below the bottom. One solution to this problem can be to log while drilling (LWD). Alternatively depending on what type of logs or what interval must be logged, cased hole logs can be run inside the casing or open hole logs can be run out the bottom of the casing to log intervals of interest. Other formation evaluation tools such as core barrels and testing equipment can be adapted to the wire line retrieving tools and then used conventionally once latched into the casing.

The technique for running open hole logs that has been found most effective, is to drill to TD with the final casing, release the bit, and then ream back to the previous casing shoe. The logs are then run through the casing just as they would be if the well were drilled conventionally. Once logging is completed, the casing is reamed back to bottom and cemented. This eliminates the need to trip all the way out of the hole and provides a way to continuously circulate the well in case it begins to flow.

viii. Cementing and Drilling Out the Shoe

In casing drilling, once the casing is drilled to the casing setting depth, the BHA is wire line retrieved. The casing will not have a float collar to land the cement plug. To overcome this problem, the displacement plug must land and latch into the casing and serve as a float. The plug and cement in the shoe joint must then be drilled out with an under reamer and pilot bit assembly connected to the next smaller size of casing.

ix. Directional Control

A limited amount of directional work with steerable motors for both deviation control and to a planned target has been done with the 7-in. casing during the phase one and two trials. The directional BHAs could be run and retrieved with the wire line without any difficulty. The directional drilling performance was similar to the directional performance experienced when drilling at Lobo with drill pipe.9

x. Well Control

Many well control incidents occur while tripping pipe. These well control incidents are avoided with the Casing Drilling process because pipe tripping is eliminated. But some kicks are taken while drilling ahead, and Casing Drilling will not prevent these.

xi. Coring

Coring operations with casing can be conducted in two different ways:

- The first method involves running conventional core barrel (both inner and outer barrel) and core bit below the DLA and using an under reamer above the core barrel to open the hole to the full dia. Core sample can be taken at any time and drilling can resume with little delay after coring.
- The second method involves using the bottom joint of casing as the outer barrel and only tripping the inner barrel attached to DLA. This method allows larger core to be taken and also drilling ahead by replacing inner barrel with a drill plug.

2.4. Casing Drilling with Non-Retrievable Assemblies-Weatherford System

Drilling with Casing (DwC) technology utilizes the casing string as a drill string so that casing is landed on bottom during the drilling process rather than later in a separate installation process. Many areas of the world have used the practice to drill-in the final tubing string and cement in place with the drill bit still attached. Modern drilling with casing is not limited to only the final string of the well. In fact most modern DwC jobs involve drilling the surface hole and intermediate hole sections.

There are two basic technologies used for Drilling with Casing. The first technology uses a bottom hole assembly comprised of

- a positive displacement motor (PDM)
- drill bit and
- hole opener

The assembly is latched to the first joint of casing. As the assembly drills ahead, the casing is lowered into the hole, either in a static or rotated mode. Upon reaching total depth (TD),

the latch-on bottom hole assembly is recovered with a special retrieval tool. A valve system is run and installed before cementing commences.

The second technology utilizes only casing to transmit rotary torque and weight to the drill bit. A drillable drill bit and valve assembly is made up and run with the first joint of casing. The casing string is rotated during drilling, typically with a spear assembly that provides rotation to the casing.

Upon reaching TD, the casing can be cemented immediately, with no need for an additional trip. Both the DrillShoe tool and the float collar normally would be made-up to a casing joint. When TD is reached and circulating bottoms-up, cementing can begin immediately, since a float collar is present in the string throughout the drilling operation.

The DwC system is a step-change technology that transforms well construction efficiency. There are worldwide DwC applications in which operational problems can be avoided and financial savings can be realized.

Benefits include reduced rig time, operating costs, flat time and operational time, as well as improved and simplified well construction operations. In addition, DwC eliminates hole and casing running problems, improves drilling efficiency by eliminating some flat spots in the drilling curve, improves well bore quality, reduces risk, and the ability to cement almost immediately upon reaching TD.

2.4.1. DwC Tools

i. Casing Drive Systems

The requirements for turning the casing in casing drilling system are identical to those for conventional drilling. The hoisting equipment must hold the weight, apply rotational torque and contain pressure.

Figure 12- A Typical Casing Drive System

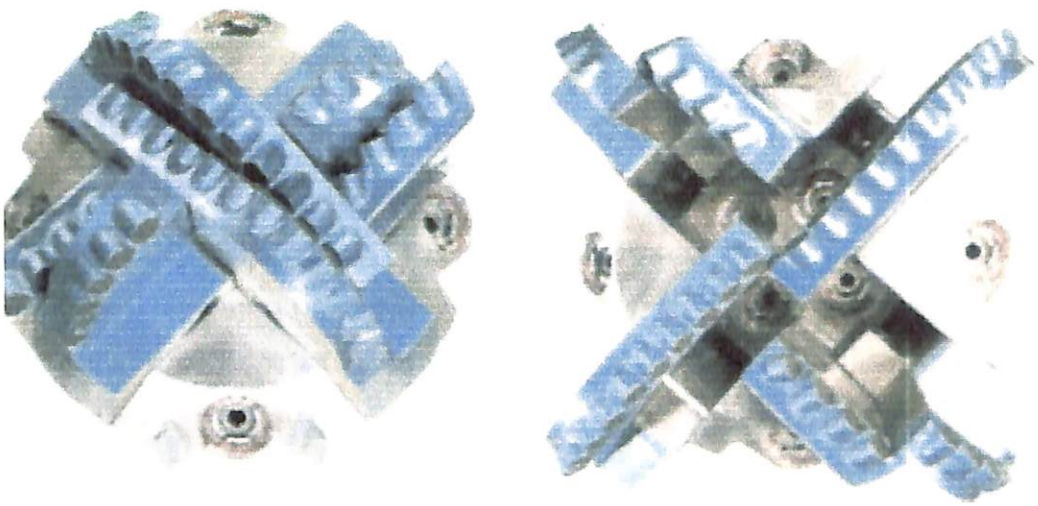


Rotary drilling with casing required a method of connecting the top drive to the casing, to drive the casing string. Extending the depth range required the development of both a fit-for-purpose internal and external grip casing drive system. The slip area of the internal grapples was significantly increased, to spread the forces over a larger area, to maintain acceptable load forces for extended length of casing. The tool is designed for quickly connecting in the casing to minimize connection time. A stop ring is positioned near the top of the spear to ensure the grapples are engaged in the proper location inside the casing. A simple quarter turn to the right engages the spear to hold the casing string and apply rotational torque. A quarter turn to the left, without axial load, releases the tool. Pumping energizes the packer element. A mud saver valve can be incorporated to minimize spillage on connections.

ii. Drillable Casing Bits

The leading component in this step change technology is the Weatherford DrillShoe drillable casing bits. Weatherford has introduced a range of proprietary drillable bits for casing drilling applications that are made up directly onto casing.

Figure 13-Expandable Bits



Expandable bits: Shown in both closed (left) and expanded (right) positions,

Expandable bit is one of the newest advances in drilling with casing technology. It incorporates many of the features of a standard PDC bit while drilling a 40 percent larger hole, and is designed to replace a conventional hole opener.

These casing bits have been designed to emulate the standard features of conventional drill bits in a drillable package and have been developed through three generations

Drill-Shoe I is designed for drilling very soft to soft unconsolidated rock, typically surface hole, in sizes ranging from 95/8 to 20 inches. Benefits include rapid and damage-free drill out, and suitability for applications with standard buttress or premium casing connections.

DrillShoe II is for-consolidated formations. Its features are:

- PDC cutters along with a proprietary diamond cutting structure
- the ability to run on most standard casing and liner drilling systems, and
- Interchangeable drillable nozzles that optimize performance.

Its size ranges from 5 to 20 inches. The cutting structure's design in the first two generations is a balance between the need to drill ahead and the requirement for the cutting structure to be subsequently drilled out.

DrillShoe III features a PDC cutting structure mounted on displaceable blades. Once the casing string has been drilled to TD, a ball is dropped that seals off the flow path, resulting in a pressure increase that forces the inner piston downward, displacing the PDC cutting blades into the annulus. Cementing ports on the inner piston are exposed once the blades are completely displaced. It is designed for more competent formations and longer drilling intervals. It combines the benefits of a PDC cutting structure with the ability to displace its non-drillable cutting structure into the annulus, leaving only drillable materials in the path of the following drill string.

PDC Bit Enhancements

Diamond Oil Well Drilling Co. has developed Torque Master Series PDC bits has incorporated new proprietary blade design and cutter placement technology enhancements for faster penetration rates, as well as continued utilization of shield inserts for improved durability. The Torque Master PDC bit has consistently demonstrated superiority in eliminating deviation problems associated with bit weights up to 35,000 pounds while maintaining above average penetration rates. Its anti-whirl and anti-stick technologies, and enhanced proprietary hydraulics program has provided excellent results with directional drilling to maintain good tool face integrity. They also efficiently steer the product to target, resulting in a very smooth and low-torque application.

iii. Tubulars and Connections

When designing the casing string for a drilling with casing application, the additional stresses applied to the casing during the drilling operation must be considered. The effect of buckling, wear and fatigue must be addressed to ensure the integrity of the casing string is not compromised either while drilling or for the expected life of the well. To date the majority of shallow casing strings have used standard buttress connections without incident. Some API standard casing threads have been tested to destruction, showing these connections would withstand three times normal make-up torque prior to being damaged. For longer casing strings, high torque connections are required. Part of the engineering process prior to drilling with casing requires a careful analysis of the torque requirements. Based on the results of the torque analysis, an appropriate connection should be selected. A number of proprietary connections available "off-the-shelf that are suitable for most applications with higher torque requirements.

iv. Centralizers

In the surface and conductor casing intervals when drilling with casing, the use of centralizers is not common. While there are numerous commercially available centralizers, most are not suitable to stand up to the rigors of drilling when rotating the casing.

Rigid alloy centralizers wear too quickly for most applications and become ineffective or can be lost in the hole. Steel non-rotating centralizers can be effective for applications with low total revolutions and where high rotational speeds are not required.

The best technical solution from a centralization and stabilization standpoint is rigid centralizer subs with hard facing applied to the gage portion. These tools add cost to the system and in some cases increase the torque required to turn the casing string. Bow-spring centralizers have been successfully run on a vertical well. This system used a positive displacement motor to drive the drilling assembly and required minimum rotation of the casing string.

2.4.2. Benefits Of Drilling with Casing Systems

i. Time Reduction

A key benefit of drilling with casing, regardless of the system used, is time reduction. With a "cement in place" system, there is nothing to remove from the hole and no requirements to place hardware in the casing prior to cementing. The float valve is in place during the drilling operations. Once the hole is suitably clear of cuttings, the cementing operations can begin as normal. The time associated with tripping pipe and running casing, including much of the circulation time involved, is removed. This results in very Small "flat spots" in most operations. Typical time savings are in the range of 30% of the time from section "spud" to LOT. Time savings of over 80% have been achieved in one case; however, not all of the time savings are directly attributable to the drilling with casing operation.

ii. Problem Reduction

Many typical drilling problems are eliminated or reduced when drilling with casing. Problems associated with formations and well bore conditions that deteriorate due to time exposed to drilling fluids are reduced simply because the exposure time is reduced. Instances of lost circulation and stuck pipe have been very limited. In over 300 field runs, not a single case of lost circulation has been reported outside of severely depleted zones where losses are inevitable. In the same 300 wells, the only case of stuck pipe was due to rig operation problems that resulted in the pipe remaining stationary without circulation for an extended period of time. Clearly the casing-drilled wellbore is in better condition than with most conventionally drilled wells. There are a number of factors at work here. It is reported that the process of casing drilling may mechanically aid in building and maintaining an impermeable "filter cake" on the well bore wall. A plastering effect on the borehole wall seals against permeable zones, reducing lost circulation and helping to prevent differential sticking. In addition, the inherent stiffness of the casing string in the well bore produces a less tortuous hole, providing a smoother well bore and reducing the risk of key-seating and mechanical sticking. The stiff assembly also is less prone to vibrations, reducing the mechanical impact damage on the borehole wall. Drill string vibrations have been attributed to bore hole stability problems.

Stuck pipe is the second most significant cause of trouble time when drilling conventionally at Lobo. Yet only one incident of stuck pipe has occurred while Casing Drilling 22 wells there. This occurred at the intermediate casing point when the kick discussed previously was taken and returns were lost. The stuck pipe occurred while the pipe was left stationary to preserve the BOP seal while circulating out the kick. Even though the pipe became stuck, the BHA was retrieved and the well was saved. No time was lost due to stuck pipe. This would not have been possible with conventional drilling technology.

Tripping of the drill string itself has been attributed to may problems such as lost circulation, borehole stability problems and well control incidents. Elimination of pipe tripping eliminates many of these problems. Running casing into a pre-drilled well bore is sometimes problematic resulting in lost time "fighting" the casing string to bottom, setting the casing string off bottom, or tripping the casing string and making a wiper trip with a rotary assembly. In areas where these problems are prevalent, drilling with casing or simply reaming with casing can be an attractive alternative to conventional casing running operations. Using a system designed to drill with casing as a tool to get the casing to bottom either by drilling it down or simply reaming it through the problem zones can be a viable alternative in many cases. This operation has proven successful in cases utilizing both liners and long strings.

iii. Drilling Safely Through Depleted Zones

One would normally expect lost circulation to be a potential problem with Casing Drilling because the smaller annular clearance between the casing and borehole wall increases the frictional pressure losses, thus increasing the ECD. In fact, what has been found is that Casing Drilling significantly reduces lost circulation. There is substantive evidence that the Casing Drilling system can be used to drill through weak depleted zones without the massive lost circulation that so frequently occurs when drilling with drill pipe and collars. It is believed to be the result of mechanically smearing drilled solids into the face of the borehole. The axial misalignment of the casing that causes coupling wear also provides a constant mechanical force on the rotating couplings to smear drilled cuttings and mud

solids into the borehole wall. This plastering effect mechanically builds an impermeable filter cake.

iv. Improved Well Control

Many well control incidents occur while tripping pipe. These well control incidents are avoided with the Casing Drilling process because pipe tripping is eliminated. But some kicks are taken while drilling ahead, and Casing Drilling will not prevent these.

v. Fluid Requirements

Compared to conventional drilling operations, experience has shown flow rates can be reduced substantially in casing drilling. As annular volume is reduced dramatically, hole cleaning is improved due to the higher annular velocities achieved, even with reduced flow rates. Cleaning the hole more efficiently and removing cuttings faster aids in ECD reduction. However, higher annular velocities and the resultant friction losses in the annulus increase the ECD. Each application must be evaluated to determine the balance that must be struck between flow rates to clean the bit face and clear the annulus of cuttings, and ECD management. Once all factors have been considered, the proper flow rate and nozzle configuration can be selected.

An inherent benefit of drilling with casing is the 'monobore" annulus. Conventional drilling assemblies result in different annular velocities around each drill string component. This can lead to wellbore erosion around drill collars and inefficient cutting transport around the smaller diameter drill pipe. With casing as the drillstring, the annular space along the entire wellbore is virtually equal allowing the optimum hydraulics to be "dialed in" based on the fluid properties, cuttings concentration and flow rate. Hole cleaning ECD management and hole cleaning are much easier. Hole cleaning has not been an issue on previous wells. While no caliper log data is available, lag time and cement returns do not indicate borehole enlargement to be an issue.

vi. Faster Fishing Through Casing by Wire Line

It is possible to conduct conventional fishing operations to recover junk from the hole while Casing Drilling. A fishing operation was conducted using conventional tools (mills, junk baskets, magnets, etc). The only difference was that these tools were run in and out of the hole with the wire line, thus making the process faster than having to trip the drill string each time a fishing run was made. The casing may actually be used similar to wash over pipe to assist in the fishing operation.

vii. Better Deviation Control

For soft formations no particular measure is needed for deviation control. However for harder formations drilling assembly can be changed as often as required to match the cutting structure as per the rock strength. Well deviation is controlled by using a stabilized drilling assembly protruding below the casing.

viii. Smaller Rigs can be Used to Drill Wells

Wells can be drilled with the Casing Drilling system with smaller rigs than are required for conventional drilling. This has a direct advantage in situations where the rig and a conventional drill string must be transported by helicopter. It also may allow smaller rigs that have been left on platforms for repairs and re completions to be used for sidetracks and infield drilling without needing to bring in a larger rig.

2.4.3. Future Developments of Drilling with Casing

Weatherford is continually developing new products and processes to advance the field of drilling with casing, some of these new product developments include:

- **Fourth Generation Cutting Structure-** PDC bits that can be drilled through with other PDC bits
- **Subsea Completions and Deepwater Operations-** Running and landing the wellhead while drilling
- **V Generation "Replaceable" Drillshoe™ Tool** - Wireline replaceable *Drillshoe* Tool
- **Greater Depth, Greater Speed-** +3500' section lengths, 100 ft/hr ROP

i. Drilling with Liners (DwL)

Liner drilling systems have been used for penetrating high pressured formations into deeper depleted zones. Liner drilling extends casing points in environments where pressure gradients are increasing with depth. The practice should be considered an alternative for reducing trouble time and reaching objectives in critical, narrow-margin wells. The concept relies on managing annular fluid pressure around the large-diameter liner to create favorable equivalent circulating density (ECD) profiles that allow penetrating farther into narrow pore pressure-fracture gradient windows. However, as liner drilling proceeds beyond normal limits, risks must be managed for making drilling connections, liner cementing and maintaining well control. The approach is consistent with ongoing industry focus on managed-pressure drilling using conventional drill-strings.

In this concept, the hole is drilled - with a conventional drill string - to traditional well control limits, e.g., a kick tolerance limit. The drill-in liner is then run, mud weight is reduced and drilling continues. In some circumstances, this concept may allow significant extra interval to be drilled beyond conventional limits, thus increasing the chances of reaching deeper objectives. Other benefits include reduced stuck pipe consequences and added capability to kill underground blowouts. The liner drilling process results in installation of full-strength tubular in the well. Liner drilling may also be used prior to reaching conventional casing points to mitigate cyclic fluid losses and fluid gains (ballooning effects) that often plague narrow-margin drilling.

Applications for Drilling with Liners include:

- Depleted formations
- Unstable formations
- Loss zones
- Pressure zones
- Salt dome drilling
- Moving/swelling formations
- Excessive hole caving

The Weatherford Drilling with Liner System uses the following components:

- Drillable casing DrillShoe™ Tools
- Auto Fill Float Valve
- PHS Hydraulic Set liner hanger
- TSP top set packer
- Single Wiper Plug with ball seat
- Retrievable Seal mandrel
- Rotating running tool
- Floating Junk Bonnet
- Drill pipe to surface

2.4.4. Emerging Trends

Although it's been nearly 40 years in the making, the casing while drilling technique seems to be entering a new phase, transforming from a thin niche to a larger slice of the drilling market, as fit -for-purpose tools become available and ideas for more applications build on earlier successes. The growing acceptance of Casing While Drilling (CWD) has spawned commercialization of related technologies to address issues ranging from casing running to new connections to formation evaluation. This has resulted in specialized rig designs, pipe-handling systems, logging and downhole tools, and software. Applications include extending casing points, drilling with surface conductor and underbalanced drilling - on both land and offshore - to name just a few.

i. Fit for Purpose Rigs

Lowering drilling costs - especially in marginal wells/ fields - is a prime reason for using the CWD technique. Improved safety is another. Wells in some South Texas locations are being casing drilled with only three strings of casing that previously required four strings when conventionally drilled. Activities are under way to demonstrate that combining underbalanced drilling techniques with CWD can further reduce drilling costs.

Tesco, which has been a pioneer in the technique, continues to provide three purpose-built CWD rigs in South Texas.

Two are operating for ConocoPhillips, where more than 75 wells have been casing drilled with Tesco's system. These wells show the advantages of the casing while drilling process in reducing lost circulation, stuck pipe and well-control incidents in areas prone to having these problems.

The third CWD rig is working for Apache in an area where low-reservoir pressure results in non-economic production rates with conventionally drilled wells.

ii. New Casing Running System

Tesco initiated a commercial casing running service that uses casing handling tools developed for CWD. This service provides a more efficient and safer casing-running process when used with a top drive by reducing floor activity and the need for a stabber to work in the derrick. Casing tongs and elevators are eliminated, as well as any need to work off scaffolding on the floor. The casing running system offers the ability to rotate and circulate each joint of casing as it is run.

iii. Formation Evaluation

Adequate formation evaluation is accomplished with through-casing evaluation tools. Although such tools have been available as cased hole services for many years, recent advances in through-casing logging from all of the major service companies have mitigated this as an issue to a large extent. A good example is Schlumberger's Analysis Behind Casing suite (ABC). These logging tools incorporate electrical, nuclear, acoustic and formation sampling tools and methods.

iv. Combining CWD, UBD and Managed Pressure

During recent attempts to lower drilling costs in several South Texas fields, an unlikely yet surprisingly practical blend of several oilfield technologies has been developed that may set a substantial, cost-effective trend in the evolution of drilling techniques. The process involves a combination of Underbalanced Drilling (UBD) and CWD, while simultaneously using Managed Pressure (MP) to widen the window of pore-pressure ranges that can be addressed in open-hole, while isolating pressures and rendering them harmless to the formation's integrity.

The inventive method, dubbed UBCD-MP, has the potential to eliminate the need for one or more intermediate casing strings. This major sidestep in the drilling process could dramatically reduce cost. The process also has the potential to cut a sizeable amount of drilling costs in "small opportunity" wells where production is uneconomic, as well as larger production areas where additional cost-effective measures would simply add to the bottom line.

Conventional overbalanced drilling limits the window of pressure management. Weak rock or a pressure-depleted zone can complicate the driller's ability to achieve the next casing seat. The UBCD-MP technology blend can increase the window of pressure management in such cases, which could make the difference in attaining TD in a deep well or finishing a well with three casing strings instead of four.

2.4.5. Other Applicabilties Of CWD

Experience gained drilling various wells with the Casing Drilling system provides insight into other applications that may benefit from Casing Drilling technology. The system obviously trips faster, but discovering its effectiveness for drilling in lost circulation prone areas is one of the most significant results from the Casing Drilling project. The Lobo experience strongly indicates that Casing Drilling can be used effectively to drill through depleted zones that are difficult to drill conventionally and which are becoming more commonplace with increasing drilling in mature fields.

- Deep Water Applications
- Under Balance Drilling
- Use Of CWD With Air Drilling
- Use Of Single String Of Casing From Surface To TD
- The Ultimate Drilling Solution May Be A Combination Of Casing Drilling With Expandable Tubulars

i. Deep Water Drilling

A tight operating window between fracture and formation pressure characterizes most deepwater drilling. The consequence is that as many as seven, eight, or more, casings may be needed to reach deep drilling objectives. Industry has become adept at managing the balance of mud weight, equivalent circulating density (ECD), trip margins, lost circulation material treatments and other operational aspects to try to push the casing points. However, this balance is difficult, and problems occur frequently. Deep Water wells are inherently expensive. However, when problems occur, they can be extensive, and cost overruns commonly approach 50% and more. With the introduction of Casing Drilling lost circulation, stuck pipe and well control issues have all but disappeared on wells. This was an unexpected benefit, but clearly one that has tremendous potential in the deepwater environment.

ii. Directional Casing Drilling

Vertical wells can sometimes be drilled with casing using a simple system consisting primarily of a special bit attached to the casing that can be drilled out to run subsequent casing strings. But when there is a need to drill with a motor without rotating the casing or the section cannot confidently be drilled with a single bit, then a retrievable drilling assembly that can be recovered and re-run is required. Even some sections that can be drilled with a drill-out bit may be more cost effectively drilled with a retrievable system. A retrievable Casing Drilling system is required for directional wells because of the need to recover the expensive directional drilling and guidance tools, the need to have the capability to replace failed equipment before reaching casing point, and the need for quick and cost effective access to the formations below the casing shoe.

Casing Drilling of directional wells provides a practical alternative to drilling the wells conventionally and then running the casing as a separate process. It assures that the casing can be run to TD and it captures many of the savings that have been proven while Casing Drilling vertical wells. For larger sizes of casing, no loss of efficiency occurs while drilling with the steerable tools below the casing. This allows the operator to take full advantage of the faster tripping and trouble avoidance benefits provided by Casing Drilling. Tesco

typically pulls the BHA with a wireline unit, but this will require a higher capacity wireline unit when a directional assembly is used in the larger casing sizes. Directional drilling with smaller size casing may sacrifice some drilling efficiency due to the requirement to use smaller motors and is most advantageously applied in situations where the Casing Drilling system provides an enabling technology rather than an improvement in efficiency.

iii. Underbalanced and Casing Drilling

Casing Drilling also seems to have application for drilling in under balanced situations. One of the next goals for the Lobo development is to try to eliminate a string of casing by drilling from surface casing to TD with one string of pipe instead of two. This may be accomplished by drilling with a rotating head so the deeper zones can be drilled with a much lighter mud weight than is currently used. An obvious advantage to under balanced drilling with casing is that the well does not have to be balanced with heavy mud to trip out of the hole to run casing, as would be required with a conventional system. Wells can be drilled with the Casing Drilling system with smaller rigs than are required for conventional drilling. This has a direct advantage in situations where the rig and a conventional drill string must be transported by helicopter. It also may allow smaller rigs that have been left on platforms for repairs and recompletions to be used for sidetracks and infield drilling without needing to bring in a larger rig.

There are also potential applications that require a little more development. Equipment to allow the Casing Drilling system to be used while air drilling is under development and modifications to the system to allow it to be used in deep water applications are in progress. The ultimate drilling solution may be a combination of Casing Drilling with expandable tubulars, but there are several hurdles that must be overcome for this to be practical.

Advantages

- Safer than UBD with Drill pipe (no tripping of drill string)
- Can eliminate intermediate strings of casing
- Drills faster

Result

- Improved production
- Reduced time on location
- Saves money

2.4.6. Cementing Process Of Weatherford System

Weatherford casing drilling system uses non retrievable assembly to drill to the total depth. Once the bit reaches to the bottom casing is done in-place, i.e. without retrieving the BHA assembly. The steps involved in the cementing process are:

Figure 14-Drilled To TD

Drill casing down and pick up off bottom-the bottom hole assembly when reaches to the required depth the assembly is picked up slightly off bottom

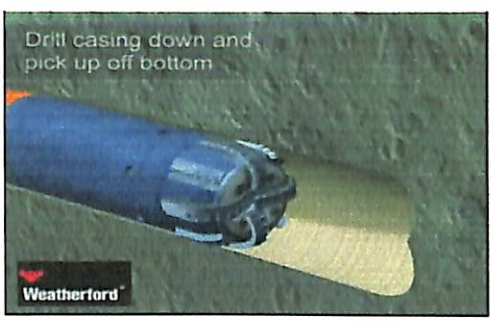
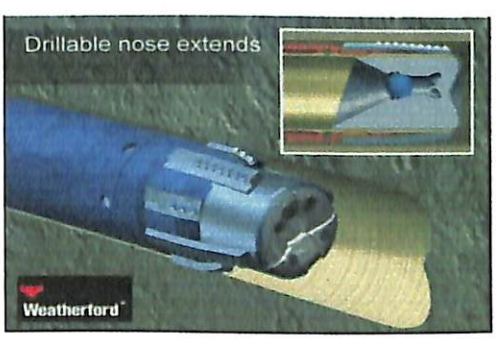


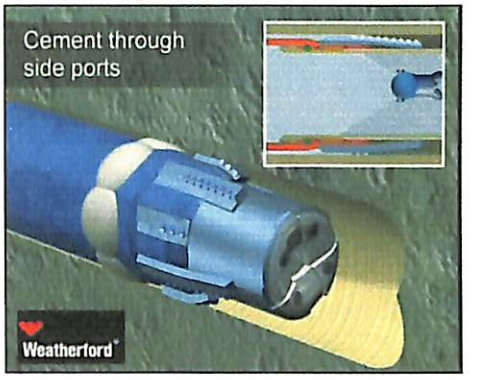
Figure 15-Drillable Nose Extended



The second step involves landing of setting balls in the float valve. Once the ball lands in the valve extra pressure is applied from the top. This forces the drillable nose to extend out and get locked.

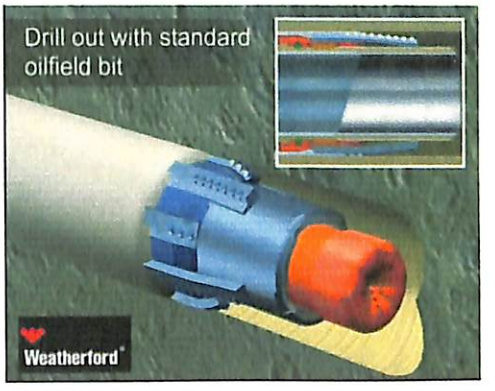
In the next step cement is pumped from the top which is forced out of the casing through side ports into the annulus.

Figure 16-Cement Pushed Out Through Side Ports



Once the cement has been set, the whole BHA is drilled out by a standard oilfield bit.

Figure 17-Next Section Drilled



2.4.7. CWD Equipment Classification System

To provide a starting point for selecting the appropriate CWD system configuration for a particular application, Mobil has proposed a CWD classification system. It includes two major classes of CWD systems--"NCR" where there is No Casing Rotation required, and "CR" where Casing Rotation is required. In each of these classes, there are a number of equipment configuration options that have already been used or are being considered.

With input from a wider group of interested parties, this classification system is expected to evolve into an industry-standard nomenclature for referring to CWD technology.

Proposed classification of CWD options

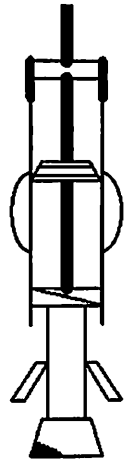
- NO CASING ROTATION (NCR)
- CASING ROTATED – Speed Depends On Whether Motor Included Or Not

NCR is again classified into further two systems:

i. NCR 1

- Casing/liner to running tool, drill pipe to surface
- Bit and under-reamer turned by motor assembly run on inner string. Swab cup above motor assembly.
- Assembly pulled on inner string
- Cementing possible before POH with bit

Figure 18-NCR 1



Special Tools

- High torque running tool
- Swab cup for cementing; after pulling bit inside casing.
- Centralizers on casing for cementing.
- Stabilizer inside casing
- Mud motor
- Under Reamer
- Bit (casing drift size)

Advantages vs Normal Operations

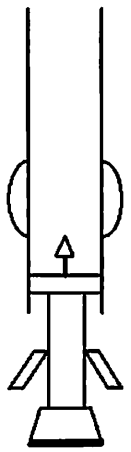
- On bottom circulation can be maintained at all times which permits shallow water flows to be controlled effectively.
- Once a flow has started serious hole enlargement can compromise the stability of the conductor in the well and in any adjacent wells.
- In normal operations flows can start during tripping when control is impossible

ii. NCR 2

- Casing to surface
- Bit and under-reamer turned by motor assy. latched into bottom joint of casing string,
- Assembly pulled on wireline.
- Cementing possible only after POH with bit.

Special Tools

Figure 19-NCR 2



- Drilling rig equipped to run casing, pump into it and run wireline inside it.
- Centralizers on casing
- Wireline retrievable latch-in Sub just inside casing shoe MWD Mud motor
- Under Reamer
- Bit (casing drift size)

Advantages vs Normal Operations

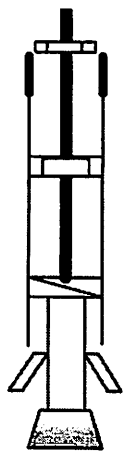
- No drillpipe tripping required.
- Adequate annular velocities for hole cleaning can be achieved at lower mud flow rates compared with drilling with drillpipe in the hole.

Casing Rotated system is further classified into two different categories which are again categorized. Their descriptions are as follows:

iii. CR 1

- Casing/Liner to Running Tool, Drillpipe to surface
- Bit and Under-Reamer turned by motor assembly run on inner string below casing spear.
- Assembly pulled on inner string

Figure 20-CR 1



Special Tools

- Pack-off activation tool Liner hanger with pack-off
- Bumper subs
- Internal casing spear (LH release)
- Stabilized mud motor inside casing shoe
- Under Reamer
- Bit (casing drift size)

Advantages vs Normal Operations

- Avoid struck drilling assemblies.
- Get required liner size into the top of the target depleted reservoir.

iv. CR 2

- Casing/Liner to Running Tool, Drillpipe to surface
- Bit and free rotating Casing. Shoe Core Bit sub turned by motor run on inner string.
- Bit pulled on inner string

Figure 21-CR 2



Special Tools

- High torque running tool
- High by-pass hanger
- Integral liner top pack-off (All hydraulic set)

- Bumper sub
- Motor landing sub
- Mud motor
- Core bit drive spline
- Core bit sub (free rotating)
- Bit (casing drift size)

Advantages vs Normal Operations

- Avoid struck drilling assemblies.
- Get required liner size into the top of the target depleted reservoir.

v. CR 3

- Casing/Liner to Running Tool, Drillpipe to surface
- Bit and fixed Casing Shoe Core Bit (or under-reamer) both rotated from surface.
- Bit pulled on inner string or left downhole.

Figure 22-CR 3



Special Tools

- High torque running tool.
- High by pass hanger and integral liner top pack-off optional (all hydraulic set).
- Production liner (may be slotted pipe)
- Fixed core bit casing shoe or under-reamer on casing
- Bit & Stabilizer inside casing (casing drift size) or fixed Bit on casing.

Advantages vs Normal Operations

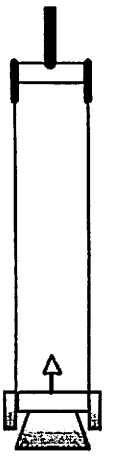
- Install production liners and gravel pack in one trip.
- Avoid struck drilling assemblies in pressure transitions associated with depleted reservoirs.
- Get required liner size into the top of the target depleted reservoir.

vi. CR 4

- Casing/Liner to Running Tool, Drillpipe to surface
- Bit and Casing Shoe Core Bit both turned by rotated from surface.
- Bit pulled on wireline or left downhole.

Figure 23-CR 4

Special Tools



- By-pass flow nozzle sub
- High torque running tool High by pass hanger Integral liner top pack-off
- Casing connections suitable for drilling conditions
- Fixed core bit casing shoe. Wireline retrievable latch-in sub just inside casing shoe. Bit (casing drift size)

Advantages vs Normal Operations

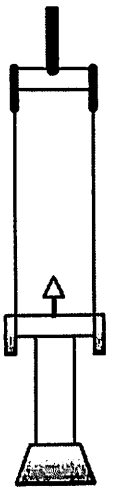
- No drillpipe tripping required for drilling.

vii. CR 5

- Casing/Liner to Running Tool, Drillpipe to surface
- Casing Shoe Core Bit turned from surface. Steerable motor assembly latched in casing
- Assembly pulled on wireline

Figure 24-CR 5

Special Tools



- By-pass flow nozzle sub
- High torque running tool High by pass hanger Integral liner top pack-off
- Casing connections suitable for drilling conditions
- Fixed core bit casing shoe.
- Wireline retrievable latch-in mud motor just inside casing shoe.
- Bit (casing drift size)

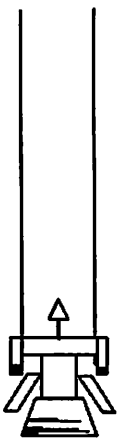
Advantages vs Normal Operations

- No drillpipe tripping required for drilling.

viii. CR 6

- Casing to Surface Bit, Under-Reamer and Casing Shoe Core Bit turned by surface rotation only
- Assembly pulled on wireline

Figure 25-CR 6



Special Tools

- Drilling rig equipped to rotate casing, pump into it and run wireline inside it.
- Casing connections suitable for drilling conditions
- Fixed core bit casing shoe.
- Wireline retrievable latch-in sub just inside casing shoe.
- Under-Reamer
- Bit (casing drift size)

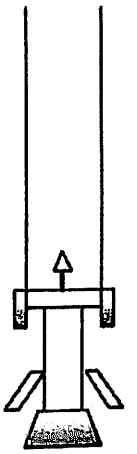
Advantages vs Normal Operations

- No drillpipe tripping required.
- Adequate annular velocities for hole cleaning can be achieved at lower mud flow rates compared with drilling with drillpipe in the hole

ix. CS 7

- Casing Shoe Core Bit with Steerable motor assy. and Under-Reamer latched in casing.
- Assembly pulled on wireline

Figure 26-CS 7



Special Tools

- Drilling rig equipped to rotate casing, pump into it and run wireline inside it.
- Casing connections suitable for drilling conditions
- Fixed core bit casing shoe.
- Wireline retrievable latch-in MWD/steerable mud motor inside casing shoe.
- Under-Reamer
- Bit (casing drift size)

Advantages vs Normal Operations

- No drillpipe tripping required
- Adequate annular velocities for hole cleaning can be achieved at lower mud flow rates compared with drilling with drillpipe in the hole

3. CASING DRILLING CASE HISTORIES

This section of the report consists of various case studies which will give us an idea about the applicability of casing drilling in oil fields. Also they will show the wide range of problems that can be handled by this technology. The case histories that have been taken up here are-

- British Petroleum's drilling program in Wyoming by Tesco.
- Drilling program by Weatherford in Tanggu.
- Yinggchai Basin program in South China Sea.
- Akamba field program in Nigeria Offshore.

Apart from these case histories some cases showing cost saving have also been included, so that technical and economic benefits of this technology can be assessed simultaneously.

3.1. Tesco System- Wyoming Program Overview

British Petroleum (BP) undertook casing drilling project in Wamsutter area, south of Wyoming. This pilot project was started to assess the potentials of casing drilling system in petroleum industry.

BP used the Tesco Casing Drilling process to drill the surface and production intervals of 15 gas wells, ranging in depth from 8,300 to 9,600 ft. Initially a 5 well project was undertaken to pilot-test the process for drilling development gas wells in the Wamsutter area.

The main objective was to evaluate the potential of the technology & its impact on drilling operations. The techniques proved sufficiently successful and the project was expanded to include 15 total wells.

3.1.1. Reasons for Using This Technology

Testing the CD technology at Wamsutter was considered appropriate for following reasons-

- Operating costs there were significantly less than in many other areas.
- Openhole logs were normally not required due to availability of sufficient offset well data.
- The project could be scheduled into a relatively active, funded drilling program. And, even though the probability of improving conventional performance and economics at this location was marginal, the additional wells were needed to maintain drilling schedule.

3.1.2. Type of Formation

Gas production was primarily from the Almond Sand, located at depths of 8,000 to 10,000 ft. The Almond is hard, tight sandstone with native pressures of about 11-ppg equivalent mud weight. It is overlain by Tertiary and Cretaceous sandstones and shales, with interbedded coals and bentonite stringers. This upper section of the production hole drills very fast with fresh water as the drilling fluid, but the pay interval is quite hard and abrasive.

3.1.3. Use of Conventional System and Problems Associated

Earlier on the drilling and casing program consisted of using 16 inch conductor casing which was set to about 40 ft depth. Then 11 in hole was to be drilled & 8-5/8 in casing was to be set up to 1150 ft depth. Then 7-7/8 in hole was drilled 400ft further and 3-1/2 in tubing was run and cemented as production casing.

Various problems were encountered in this program. Water flows, lost circulation in depleted zones and in a fractured zone, and bit balling in shales and bentonite beds are common.

To some extent these problems were partially overcome by making some adjustments in the drilling program. Fresh water was used for drilling up to 100 ft above pay zone. After

this depth weighted mud of about 10 ppg was used. Also use of PDC bit from surface helped in drilling up to desired depth with increased efficiency.

3.1.4. Type of Drilling Rig Used

A fully dedicated rig developed by Tesco was used in this project. The rig was equipped with full computer controlled rotating, hoisting & pumping system. Hydraulic power was used to perform all the processes. Also the rig had a specially designed casing clamp to ease the drilling process.

3.1.5. Project Description

The surface hole in each of the 15 wells was drilled to about 1,200 ft with the CD system. In each case, the BHA was installed at the surface and retrieved with wire line. A roller-cone pilot bit was used in Wells 1 and 2, while a PDC bit was used for the remaining 13 wells. The same under reamer and cutter arms were used for the first eight wells, but could have been used for all 15 wells. Clear water was circulated directly from the reserve pit at about 350 gpm for the drilling fluid.

The casing drilling system performed above par. The rate of penetration for conventional system was matched by this system. Increase in weight on bit caused due to addition of another casing varied the penetration rate between 200 ft/hr to 500ft/hr.

The casing drilling system had a great impact on saving drilling time. The depth from spud to casing point was reached in just 8 hrs. No time was wasted in drilling surface hole as there was no time investment in handling of drill collars. A conventional system would have taken about 19 hrs for drilling from spud to primary cement job completion. On a contrast casing drilling allowed the surface hole to be drilled & cemented in just 13 to 14 hrs.

Bottom hole assembly was retrieved successfully on 14 of 15 wells without tripping the casing. At times sand accumulation posed problems while retrieving BHA through wireline. In one of the well BHA was not retrieved due to sand accumulation above the packer cups. With adequate changes in design of top section of DLA prevented recurrence of this problem.

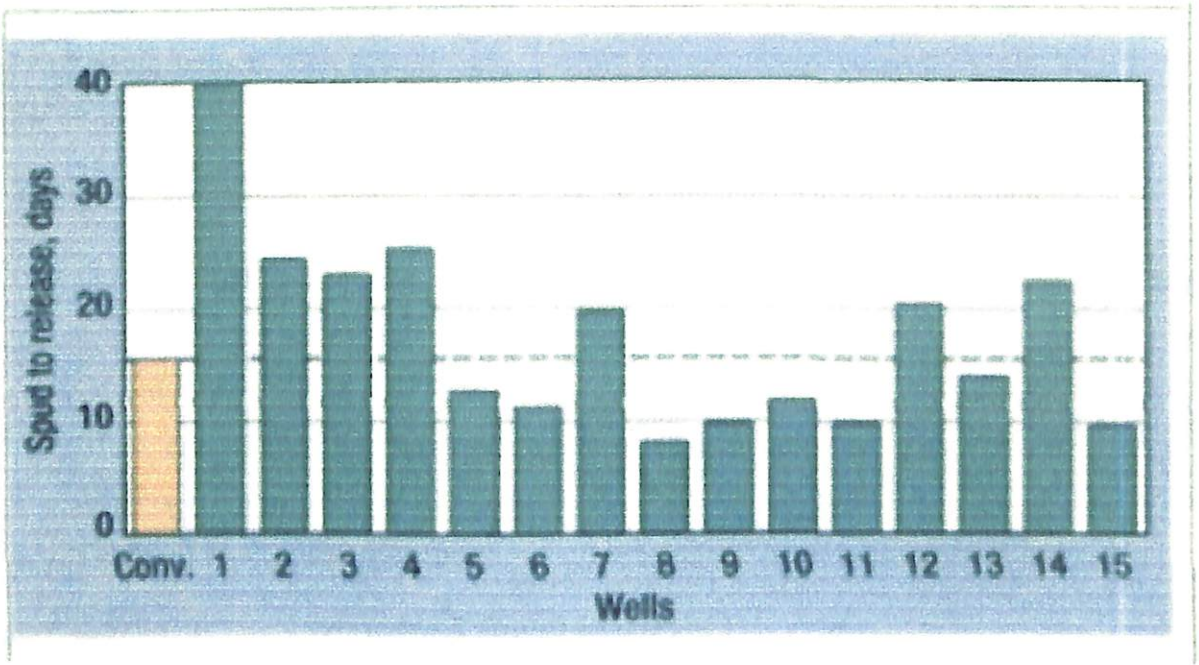
Initially the drilling time with casing drilling was not comparable with those drilled by conventional system. As the problems were identified and respective solutions were implemented, the performance of casing drilling system improved and surpassed that of conventional system.

3.1.6. Problems Initially Faced and Their Remedies

- Fatigue failures of casing connections at depths of 7,728 ft and 4,885 ft on the first two wells, respectively, resulted in fishing jobs. In one case, the bottom part of the casing was recovered, but in both cases, the remainder of the well was completed conventionally with drill pipe. The cause of these failures was a combination of high cyclical stress due to lateral casing vibrations and limited fatigue resistance of the wedge thread. To resolve these problems casing connection and casing designs were changed. This casing, threaded with a flush connection, provided additional weight to move the neutral point lower and give additional buckling resistance.
- In addition to the problems related with failure of casing, several issues with the wire line-retrievable tools were identified. Several changes in DLA were made to overcome these problems. Performance of the 4-1/2-in. DLA on these wells was quite adequate, showing little erosion after 191 rotating hours, while pumping at rates as high as 290 GPM. This performance helped in restoring the reliability of DLA during processes like retrieving and re-storing of assembly.
- Rate of penetration in initially drilled wells was less and hence the drilling time with casing drilling was not comparable to conventional system. The main reason for this to happen was balling up of drilling shoe. So for the fifth well casing-shoe/pilot-bit combination was removed and a 6 ¼ in PDC full hole bit was attached at the bottom of casing joint. After this change the wells were drilled to target depth & the production casing cemented without retrieving PDC bit. Use of full hole bit reduced the drilling time significantly. As a result well no 5 & 6 were drilled in just 12.7 & 11.2 days.
- Well no 5 to 7 were drilled without stabilization above the bit. Though the deviation was benign, the torque was comparably high. To encounter this problem a specially

designed packed-hole assembly was constructed which was integrated with solid-body stabilizers. It was used in well no 8 to 15. Significant reduction in inclination, hole tortuosity & off-bottom torque was observed.

Figure 27-Comparison between drilling time of conventional & casing drilled wells



3.1.7. Results of the Project

- Overall average of drilling time for the 11 wells drilled with PDC bit was 14 days.
- Two subsequent wells failed to reach target depth with single PDC bit. So tripping has to be done to change them.
- Initially the wells were expected to project problems like well bore stability, lost circulation & gas flow. But during the program the well bore remained stable. Target depth was reached with mud weight about 0.75 PPG lighter than conventional wells. No major threats in terms of mud loss or well control incidents were experienced.
- The limited experience of casing drilling suggests that this system helps in building & maintaining an impermeable filter cake wall on the bore hole.

3.1.8. Conclusion

- The pilot project consisting of 15 wells was quite successful. Improved well bore stability, reduction in lost circulation & minimized gas influx were observed.
- Bit performance was not very consistent even though the casing drilling performance was comparable with conventional system. With better bit performance the average drilling time will have bee around 10 days.
- In current state of knowledge casing drilling can be used for softer formations with casing size of around 7 in. If there is problem in running the casing after hole has been drilled then casing drilling is preferred. With increased confidence regarding retrieval of bottom hole assembly successfully, the use of this system could be extended to high- cost projects.
- This project also has shown that use of smaller size casing can also be made in casing drilling. The project also indicates considerable potential in use of multi stage under reamer for harder rocks.

3.2. Weatherford System - Tanggu Program Overview

Zhao Dong field is located 55 km south of the Tanggu in Bohai Bay. The drilling program comprised of 25 wells in the initial development. Surface casing depths range from 270 m to 300 m. The water depth is 7 m and rig elevation is 32.3 m above mean sea level. Weatherford's casing drilling system was used here.

Casing drilling was adopted in this field to simplify the drilling processes. With least handling of heavy equipment and reduced rigging up and rigging down processes many of the safety concerns were checked them self. The major concern of the project was to safely and efficiently install the 13 3/8 in surface casing string.

Various adjustments in the system were made to ease the working. Use of unique handling tool to facilitate safe and more efficient installation techniques, utilization of a second spear assembly to allow both drilling in the wellhead assembly and cementing through the spear, and utilization of some automated casing handling machinery to improve both safety and efficiency are some of the changes that were introduced in casing drilling system while working on this project.

Apart from the above mentioned changes various other changes were made in the drilling program. Choice of equipment was very important and depending on the type of formation, in-situ pressure and other conditions following equipment selection was made.

3.2.1. Drill Shoe

Drilling shoe's that were used in this project was designed by Weatherford under the product name of DS2. This basic difference between DS1 & DS2 was impregnation of thermally stable diamond pellets in the aluminum blades which improved the durability of bit. These drilling shoes had three bladed design with outer diameter of 16 in. two nozzles were also there to clean-up the blades. Three bladed design was used because they use to give high rate of penetration in drilling surface holes. The drill shoe used is shown below.

Figure 28-Casing Shoe DS2



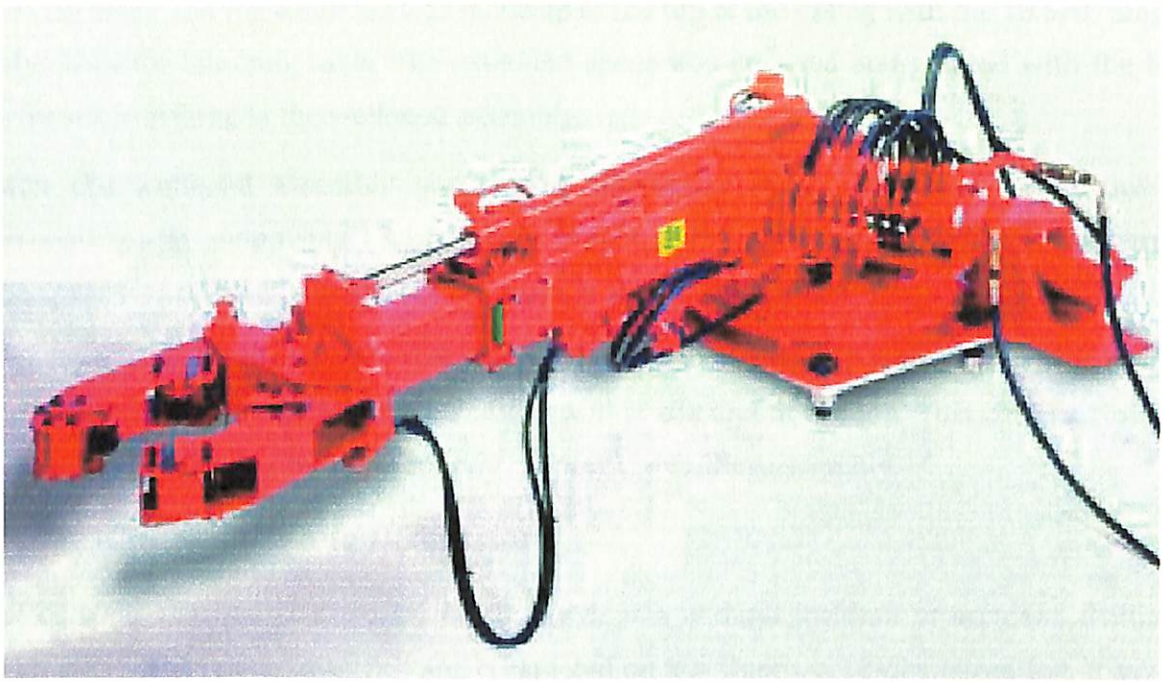
3.2.2. Casing Drive System

Generally for casing drive system Weatherford uses casing spear. Casing spear are equipment that are used for retrieving the casing which has accidently fallen into the well. In this case they apart from holding the weight of casing have to transfer torque. In this project two types of casing spears were utilized. The Standard casing spear was used for picking up and drilling down normal casing. An Extended casing spear was used to pickup and drill down last joint of casing with integrated wellhead assembly.

3.2.3. Stab Master

The stab master used in this project must comprise of a hydraulically powered remote controlled stabbing arm. Casing alignment is done by various movements in forward, backward and lateral direction. This helped in increasing the efficiency of casing connections. This system efficiently took care of concerns of safety, enhanced drilling time and reduced costs. The stab master shown below was used in the project.

Figure 29- Stab Master



3.2.4. Modified Single Joint Elevator

An 18.5/8" Single Joint Casing Elevator was prepared after analysis of the quickest and most cost-efficient option for picking up the Kvaemer wellhead for drilling through. 1/4" of the internal wall of the lower support ring was machined out to allow it to close properly around the external recess groove below the top of the wellhead. Load tests were carried out to ensure the bottom elevator ring capable of holding the weight of the wellhead.

3.2.5. Technical Challenge

The Zhao dong project was the first use of cementing through the casing spear. A second casing spear with an extension was prepared for drilling in the wellhead assembly without damaging the internal sealing of the wellhead. The function of extension was to provide adequate length so that the spear grapple could be set. The extended spear assembly was then made up with drill pipe and spaced out to provide full opening valves and a side entry sub with a closed valve to be located near the drill floor when the wellhead landed at the landing ring. Once the casing had been drilled to a predetermined depth, the normal spear

was set aside and the wellhead was made up to the top of the casing with the 18.5/8" Single Joint Elevator handling tools. The extended spear was engaged and rotated with the top drive while drilling in the wellhead assembly.

After the wellhead assembly has landed, the upper and lower valves were closed. Cementing was done using 12.5 ppg light weight slurry. As soon the well was cemented, the spear was released and the rig was quickly skidded to next slot.

The drawback associated with this system was due to absence of cement plug. Due to this the cement residue was left on the casing wall at the end of the job. This cement residue was eventually drilled by subsequently running the drilling assembly.

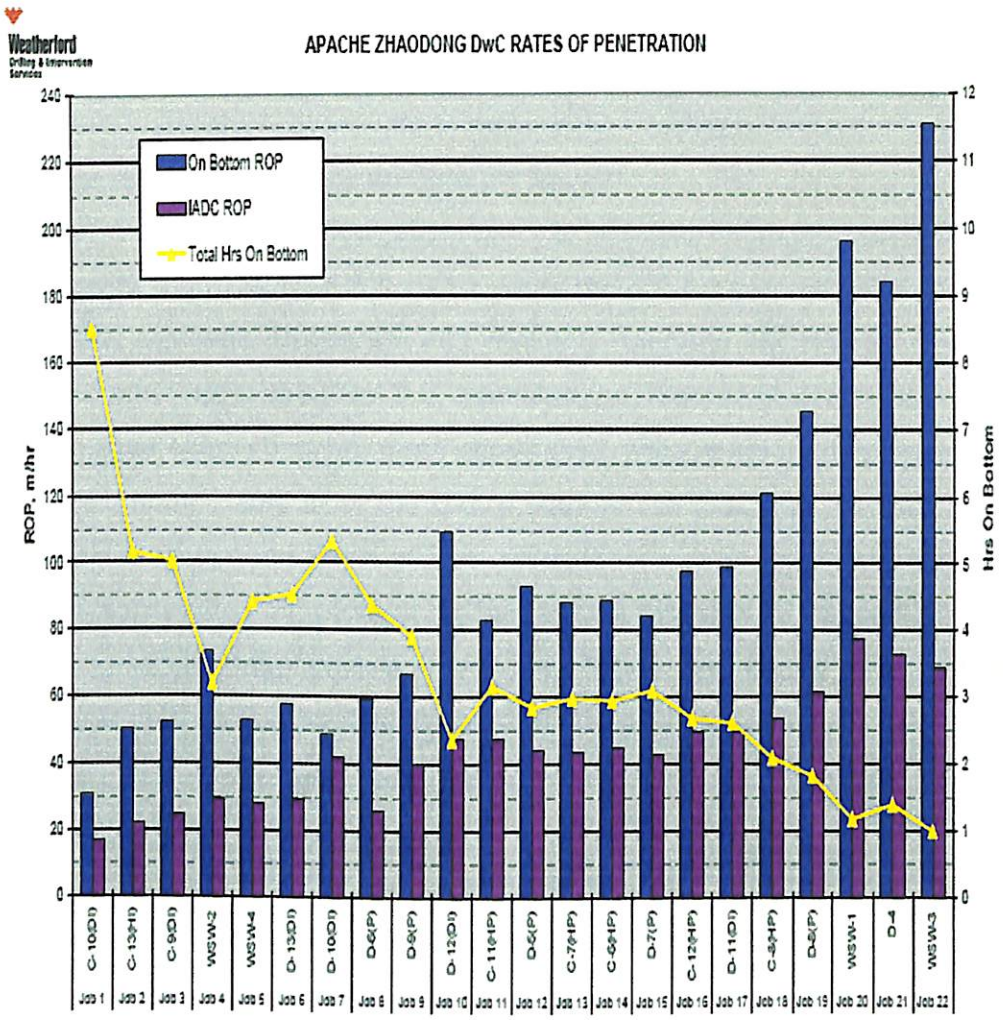
3.2.6. Results and Discussions

All 22 wells reached planned casing setting depths without incident or accident. Drilling-with-casing started on 25th Feb and completed on 9th March, a 12-day operation. It saved 21 days rig time, for installation of 13.3/8" surface casing. Based on rig rate of US$80,000 per day, company saved US$1.7million. In a day of work about 300m depth was drilled using casing, wellhead was installed and cementation of well was done. Thus in a single day this work was repeated in on 3 wells.

Some important features that came out of this project have been listed below:-

- Total depth of about 5633m was drilled in just 75 hrs. Thus an incredible rate of penetration of 75 m/hr was observed. This value is almost double of average IADC rate of penetration i.e. 37.3m/hr.
- For first five wells operating conditions were kept moderate about in range of 4000 lbs weight on bit and 60 RPM. On well no 10 RPM was increased to about 80 after drilling 40m. Tremendous increase in rate of penetration as well as torque was observed. The ROP increased from 100m/hr to 200m/hr.
- ROP for softer formation was also increased by applying higher flow rate and hydraulic horsepower. Initial hydraulic horse power per square inch on first well was about 1.52 at 817 gpm and was increased to 2.71 at 990 gpm respectively.

Figure 30-Rates of penetration on all wells



- Mean connection time of 8 min and average connection time of 12.2 min was recorded. Total connection time was 79 hrs.
- Operational time spent on each section reduced with increase in no of wells drilled. The first well drilled took about 32 hrs were as last two wells were completed in about 7 hrs in each well.
- 14 of the 22 Drill Shoes were drilled out. There was no bit damage from drilling out the Drill Shoe. No other difficulties or anomalies have occurred.
- The inclinations of the 13-3/8" shoe at TD were also proved to be negligible. All wells have experienced less than 1 degree of deviation at the shoe.

3.2.7. Future Recommendations

- Use of a split master bushing rather than a solid master bushing is recommended. This eliminates the requirement to remove the bushing before running the wellhead and can potentially save 20 minutes per section.
- Top drive and rotary bushing alignment can be improved to save connection time.
- The Single Joint Elevator will rotate when the drilling commences and it has to be manually removed. Utilization of a remotely operated SJE enables removal of the stabber and improves safety. It is estimated the remote SJE will save an estimated 2 minutes per connection, but more importantly, will greatly improve safety.
- While running casing from the rotary table to the mud line, the casing spear can function as spider and elevator. This will save rig-up and rig-down time for the bails as well as the side door elevator. Estimated time saving is 15 minutes per well.
- From the Zhao Dong experience it's established that higher RPM and WOB can significantly improve the ROP. Hydraulics also plays an important role in enhancing the ROP. Recommended operating parameters for future casing drilling job in similar geological settings are-
  - RPM: 90-120
  - WOB: 5-10 klbs
  - Flow: 900-1100 gpm
  - HHSI: >2.5

3.2.8. Conclusion

- Utilizing DwC technology provided opportunities for Apache China to safely and efficiently install 13-3/8" using batch drilling operations with a savings of 21 operating days versus the time estimates. This is a savings of US$1.7 million versus the budgeted plan.
- Less rigging up and rigging down due to eliminating handling of different types of components.
- The Zhao Dong DwC program pushed the limits of Drilling with Casing and provided better understandings of the capability, energy requirements, and performance of the DrillShoe™. It is believed higher ROP is possible with variation in weight on bit and RPM.

3.3. Yinggchai Basin Project Overview

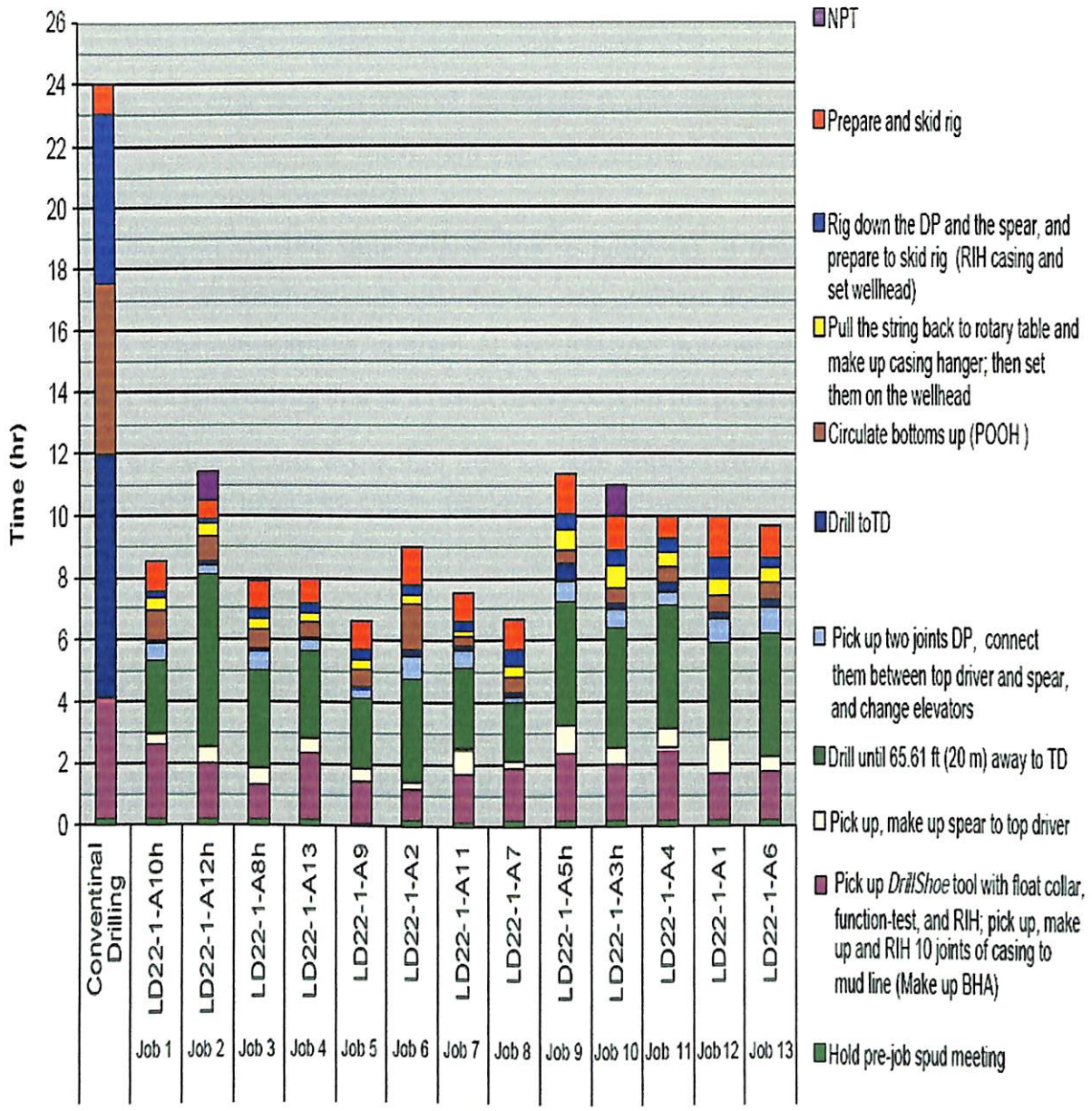
Weatherford undertook a project of CONOOC Ltd- Zhanjiang at Yinggchai Basin in South China Sea. It has to drill 13 development wells in a formation having clay, sand & loose gravel. The hole size was to be 17 in and 24 in. the casing size for eight wells was 13 3/8 in and for wells was 20 in respectively. The objective of this project were-

- To stop the leakage from a loose gravel and sediment layer at a depth of 886 ft depth. This fluid loss was casing many problems during drilling operations.
- To reduce the non productive drilling time being faced due to loose formation and fluid loss. This would help in savings on rig cost.

Result:

- The lost circulation problem was solved as the casing penetrated the desired depth. This solved the biggest problem of the drilling program. It also helped in saving valuable rig time.
- Due to use of this technology about 200 hrs of rig time was saved which was worth US $1.6 million to the client. A comparison between the casing drilling time and the time to be taken by conventional system is shown below.

Figure 31-Casing Drilling Time Compared to Conventional Drilling Time



3.4.Akamba Field, Offshore Nigeria Overview

Akamba-2 field in offshore Nigeria had two major problems-

- Fluid loss over the interbedded sandstone & clay stone section had interrupted the drilling progress very much. Also this was causing high investment for drilling fluid with no encouraging results.
- Long nonproductive time caused due to problems of fluid loss in the formation. Breaking of borehole wall was also causing problem during running of casing after drilling by conventional method. All these factors accounted for higher rig cost as rig time was increasing and as a result heavy cost on the project.

Elf Petroleum Nigeria Ltd decided to drill 12 ¼ in vertical well up to a depth of 3921 ft. casing of size 9 5/8 in and 53.5 lb/ft was chose for the project.

Results:-

- The operation was completed in three days thus saving 2.9 days of rig & crew time worth US $1.2 million. This influenced the economics of the project very much.
- The operation ensured continuous fluid return. Hence fluid loss to interbedded sandstone & clay stone sections was reduced. As a result drilling fluid cost was also reduced.
- Presence of casing in the hole all the time helped in maintaining well bore stability. Thus mechanical problems while running the casing after drilling were not present as the casing was run with drilling. This helped in saving rig time and as result money investment.

3.5.Economical Aspect of Casing Drilling

Experience with the casing-drilling test wells suggests cost savings in the 10-15% range for trouble-free wells when casing drilling can be used across intervals. For onshore wells in relatively fast drilling areas, incorporating these savings with the savings that may be realized from more-efficient rig moves and the elimination of hole problems related to tripping the drillstring could provide an overall savings of up to 30%.

In offshore applications where the day rates are much higher, the most effective applications may occur through time savings that accompany advantages of drilling larger strings of casing into place. In addition, this technology may avoid hole stability problems that occur during tripping operations. Finally, the possibility exists where an entire string(s) of casing may be eliminated.

The potential cost savings associated with drilling with casing were evaluated based on wells drilled by Mobil. The average length of hole section drilled was 1,980 ft., and an average of 220 hours were required to drill, case and cement. Of this total average time, tripping took 37 hours (17%) and drilling required 47 hours (47 %) at a ROP of 42 ft/hr.

Based on drilling with casing at similar rates and saving all the tripping time, at a rig rate of $200M per day, an average saving of $308M per well could be realized. This time-related cost saving would be offset by the additional cost of tools and service personnel required to drill and cement. It was estimated to be $38M per well. Hence, from Mobil data the average saving from using casing drilling was approximately $270M per well. For comparison, Shell estimated cost savings for a similar project was estimated to be approximately $193M per well.

Savings in materials and tool rentals would also be realized, but the time-related costs are the most significant. The additional cost of tool can be accounted for various equipments and for man power. For example following equipments will be required for converting a conventional rig to a casing drilling rig:-

- Standard surface equipments like split traveling block with split crown sheave, wire line BOP and casing drive system.
- Standard down hole equipments like drill lock assembly (DLA), casing profile nipple (CNP) and under reamer with PDC cutter arm.

Similarly expenses on casing associated accessories like casing reaming shoe, wear bands, centralizers etc have to be accounted.

Cost estimated for conversion of a conventional rig into a casing rig for Stratton field operated by Apache Corp. is shown in the table below:-

Table 1-Cost Estimation for Conversion of Conventional Rig into Casing Drilling

S. No.	Component required	Estimated cost (in U.S. $)
1.	Casing Drilling Wireline Winch	5000000
2.	Split crown blocks	150000
3.	Split travelling block	150000
4.	Wireline BOPs	50000
5.	Solids Control Equipment	85000
6.	Modify Mast for Top Drive	20000
7.	Rig Day Rate(8 days)	64000
	Total Cost Estimated	1019000

Apart from the cost required for conversion of rig there are some operational difference between casing drilling rig and converted rig. The purpose built rig takes about 1 ½ days time to rig down, move and rig up ready to spud the next well. A conventional rig will take about 3 days time. Also a purpose built casing drilling rig needs smaller space than converted rigs. That's why it can be beneficial for use in offshore locations. Hook load requirements of purpose built rig are also lesser. With automated pipe handling system on the purpose build casing drilling rig the casing handling and connection making activity become more effective. This also helps in reducing the risk associated. Some cost associated with rig operations have been tabulated below:-

Table 2-Cost of Rig Operations Per Well

S. No.	Rig Operations	Cost Per Well(in U.S. $)
1.	Rig Move Days	36000
2.	Top Drive Rig Up	24000
3.	Top Drive Rental	25000
4.	Location Construction	10000
5.	Automated Catwalk	12000
6.	Casing Drive Assembly	20000
	Total Cost Per Well	127000

A comparative economic study was done for Geleky field. The proposed interval to be drilled was from 3700m to 4500m i.e. a depth of 800m was to be drilled. Lost circulation and breaking of bore hole wall were major problems. By deploying casing drilling the project was expected to be completed in 44 days. On the other hand use of conventional drilling would have taken about 75 days. About 33 days of rig time was expected to be saved. With rig cost of about Rs. 5,00,000/ Day, casing drilling would have saved about Rs. 1.65 Crore. Apart from that the problems that had hindered the drilling progress were eliminated.

Conoco has used Tesco's Casing Drilling system to drill 17 development wells in Lobo field of South Texas since mid-2001. The intermediate and production sections of Lobo wells often require time for hole conditioning, lost circulation, gas influxes, stuck pipe and running casing.

The system has significantly reduced these downhole problems by casing the well as it is drilled. Negligible time has been required for hole conditioning and lost circulation. Gas influx has been less of a problem while drilling with casing than when drilling conventionally. Performance on the first 10 casing drilled wells shows that the technology provides time savings of 8% to 33%. With the higher cost of rigs deployed saving in a few days time does have its economic importance.

3.6. Outcome

The above discussed points have made the economics associated with casing drilling quite clear. In many of the fields due to technical complications the wells were either abandoned or use to terminate prematurely. Thus they were not able to achieve the objective set for them.

In many of the cases low cost investment required also hindered the development of marginal fields. With growing increase in demand of oil and gas technologies were bound to emerge. Casing drilling was one such solution which was widely used by Conco Philips in LOBO field of South Texas.

Since the complications are avoided by using this technology, so chances of loosing equipments like BHA, Bits, Motors etc have reduced. This reduces the cost of material and cost involved in fishing out them. At times well has to be side tracked if the fishing does not turns out to be successful.

At the end we may conclude that this technology can be employed at couple of wells and its technical and economical considerations should be closely studied. Influencing outcomes of such a pilot project may help us in making decisions regarding full use of this technique.

4. CONCLUSION

In conventional drilling system tripping process takes about 35% of total drilling time to drill a well. Also this process is labour & energy intensive. Unscheduled events while tripping like kick & stuck-up increases the drilling time. Casing while drilling can be a solution to such problem.

Casing drilling is the process of drilling & simultaneously case well by using the casing as drill string. This technique can be used as a solution to following problems:

- Swelling formations.
- Sloughing formations.
- Washouts.
- Swab oil and gas wells.
- Casing difficulties in weak borehole wall.

Advantages of casing drilling can be seen as:

- Wellbore integrity is preserved.
- No tripping and other pipe handling problems are eliminated. This also increases the safety of the process.
- Increased bit hydraulics due to smaller annular clearance.
- Lesser drilling & completion time is required. This helps in reducing the cost of the project.
- Checks drilling fluid loss from problem formation and thus helps in reducing the drilling fluid cost.

Casing drilling can be performed by the basic methods: either by using retrievable system or by using non-retrievable system. These systems were developed by Tesco and Weatherford respectively.

The basic equipment required for casing drilling are:

- Surface equipments: Top Drive System, Casing Drive System, Split Block, Wireline Winch & Wireline BOP are needed in casing drilling.

- Downhole tool used are wireline retrievable BHA or drillable bit or valve assembly.
- Other casing accessories used are Multi-Lobe Torque rings, centralizers, pump down cement float, drilling & guide shoe.

Rigs used can be either of two types: Purposely built casing drilling rig or Converted rig. Purposely build rig has many advantages over converted rig. Drilling time required is lesser due to many systems operating for handling and connections of casing. They also ensure more safety in the process. Also rig up & rig down time is lesser in casing drilling rig.

Future development of casing drilling can be anticipated in various fields such as:

- Deep Water Drilling.
- Under Balanced Drilling.
- Directional Casing Drilling.
- Use of Casing Drilling With Expandable Tubulars.

Results of Wyoming program were very encouraging. Improved wellbore stability, reduction in lost circulation & minimized gas influx were observed. Use of smaller size casing & use of multi-stage under-reamer can be made in drilling various types of formation.

Outcomes of Tanggu program were exceptional. Total depth of 5633m was drilled in just 75 hrs. Fair increase in rate of penetration was observed with increase in weight on bit and RPM. The deviation at target depth for all wells was less than 1 degree. Use of split master bushing was proved better than use of solid master bushing.

Lost circulation problem was solved in Yinggchai Basin program. The use of casing drilling saved about 200 hrs of drilling time which was worth US $1.6 million for the client. Similarly in Akamba field, offshore Nigeria, about US $1.2 million was saved by using this system.

Field results have shown rig time saving upto 30%. The problems being faced during conventional drilling were also reduced. These outcomes suggest the use of casing drilling in more enthusiastic way.

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