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FIELD EXPERIENCE WITH ADVANCED DESIGN HOLE OPENING TOOLS

Adel Sheshtawy, Nader Sheshtawy, Nada Isa and Lloyd Payne - TRI-MAX Industries, Inc.

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Abstract

Current deep well plans dictate underreaming of one or more sections of hole. The Enlarge While Drilling (EWD) and Expandable Stabilizer (ES) tools were introduced to the drilling industry in 1998 and have more than three hundred field runs.

The applications for underreaming are expanding with the adoption of the Slender Well Designs (Close Tolerance Casing [1]) which maximize production casing size while simultaneously decreasing surface casing and BOP requirements. Recently, the development of expandable casing will also lead to an increase in the need to enlarge holes.

This paper will present a summary of the EWD field applications with rotary, PDM motor and rotary steerable systems (RSS) in straight and directional wells. Also improvements in the tool design to meet the requirements of wells drilled by deep water floating units will be described.

A comparison of the design principles of new hole underreaming tools will be summarized. (Table 1)

Introduction

In the early days, the drilling industry used a pump pressure activated flip-arm underreamer to enlarge previously drilled hole. The flip-arm underreamer had to be run with limited weight on bit (WOB) and limited rotary speed in order to accommodate the fragile nature of the flip-arm cutting structure. Underreaming with this tool resulted in higher costs as a result of extra rig time and frequent fishing of the lost underreamer arms in the hole.

The bi-center bit was introduced in the early 1950’s and became popular in the mid 1980’s with the increase in deepwater drilling activities. Bi-center tools improved some of the limitations of the underreamer. The bi-center tool was the first tool which could simultaneously underream and drill the pilot hole. However, the limitations of the bi-enter bit were poor directional control, vibration and irregular spiraled hole size due to the eccentric design [2].

Symmetrically designed underream while drilling tools like the Enlarge While Drilling (EWD) tool have several advantages verses a bi-center type tool (SRWD, Quad reamer, DOSRWD, etc…). The advantages are superior directional control, longer continuous runs, faster ROP and better wellbore quality.

EWD Design and Features

The EWD enlarges or underreams a bigger diameter hole than the previous casing ID while drilling the initial pilot hole (Figure 1). The EWD held in the tripping position by shear pins will drill the float equipment. Once clear of the shoe, the tool is activated by shearing the pins. The EWD is a short (3-5 feet) tool with three symmetrical cutter blocks. The cutters are made of one block of steel and are inserted from the inside of the EWD housing. The wedge shape design of the cutter blocks prevents them from being lost in the hole. Below the cutting structure there are three interchangeable reverse jet nozzles. These jets not only clean the EWD cutters, but improve cutting removal from the bit face. The end result is the bit drills faster due to less regrinding of cuttings even with lower flow rates.

Another feature of the EWD is the mechanical activation of the cutter blocks with no dependence on the mud flow. The internal components which enable this are the upper and lower mandrels. The upper mandrel telescopes over the lower mandrel when activated and seats in a metal ring groove at the base of the lower mandrel creating a metal-to-metal seal. The EWD has no pressure or temperature limitation. This feature has been demonstrated by drilling a 4,300 ft salt section with one EWD at 387° bottom hole temperature (case history on rotary BHA).

The EWD is in its 4th generation with many improvements to the original design. The EWD was first introduced to the industry to run directly above the bit, either below a motor or on straight rotary. Now with the Rotary Steerable System (RSS), the EWD is run further up the string. The EWD lock, which has been incorporated since the 2nd generation design for extended reach applications, was further utilized to keep the EWD in the drilling position even with weight below it. As a safety feature, the lock is set to shear at a 10,000 – 40,000 pounds overpull depending on the size of the tool and operator’s requirements. (Figure 2)

Symmetrical Design Advantages

The directional steering of a symmetrical reaming tool has enabled well trajectories to be drilled which would be difficult with an eccentric tool. The use of the EWD below a PDM motor in highly directional well profiles has been demonstrated since 1998. The short length of the EWD coupled with its symmetrical design allow the motor to be oriented easier as well as reducing the chance of losing the tool face during sliding. With RSS, the EWD has proved in numerous field runs the ability to follow the smooth directional path generated by the RSS. By contrast, eccentric tools force the RSS to constantly adjust directional heading and as a result the wellbore is not as smooth. Even on straight rotary, the EWD has proven to be able to hold angle when the BHA is properly stabilized. This sometimes warrants the use of ES tool at a specific size for the application relative to the EWD.

Longer continuous runs without having to trip out of the hole have been accomplished due to several benefits of a symmetrical tool. The symmetrical design eliminates fluctuating torque due to the balanced cutting structures. This in turn lowers or even in some cases eliminates the vibration in the BHA. As a result, several types of downhole equipment (MWD, RSS, LWD, PDM motor, etc…) are able to increase their mean-time-between-failure (MTBF). A full size pilot bit of the operator's choice (Tricone or PDC) can be used as opposed to a small pilot bit demanded by a bi-center type tool's pass through requirements. This leads not only to longer bit life, but as a result the EWD is only cutting around 25% of the hole volume compared to 55% in most bi-centers. All these factors result in less time pulling out of the hole to change BHA components and more time drilling.

Faster rate of penetration (ROP) is another benefit of the tool design. The EWD cuts less formation and therefore the ROP is controlled by the bit which does most of the work. In addition, the EWD's reverse nozzles improve ROP as mentioned earlier. The better directional control below a PDM motor leads to less time spent sliding verses an eccentric tool. Sliding ROP is approximately 50% of rotating ROP.

All of the advantages stated are of little importance if the wellbore quality and hole gauge are so poor that casing cannot be run. There is a strong tendency for bi-center type tools to drill a spiral hole simply due to its eccentric design [3]. This tendency is not seen with symmetrical tools. However, symmetrical tools which rely on pressure to keep their cutters activated encounter difficulties as the angle of well increases and more weight of the BHA is being supported by the low side cutter. This will cause the formation to push the cutter back in every time it rotates to the low side of the hole. Pressure is not sufficient to overcome the vertical weight component of the BHA in this case. Finally, the EWD's mechanical design when locked allows any slight hole irregularities to be backreamed. A bi-center design requires weight to be applied on the bit so as to give it a point to pivot around. Thus, backreaming is not possible.

ES Application

The Expandable Stabilizer "ES" can be run in tandem with the EWD or on its own as an expandable stabilizer with a bi-center assembly. The ES is normally placed just above the motor and/or up to 60 feet above the EWD to aid in directional control. The ES design is based on the EWD design only replacing PDC cutter blocks with tungsten carbide inserts on a flat gauge surface.

The ES can be specified to hold, drop or build angle depending on the application. Figure 3 gives some general guidelines on ES sizing.

Case Histories Summary:

The EWD has over 300 runs and more than 300,000 feet drilled in the last four years. Three case histories from each type of BHA are discussed below.

- **Rotary BHA**

An 8 ½" x 9 ⅞" EWD was run directly above an 8 ½" PDC bit in the Gulf of Mexico, Galveston Bay. The salt section with thin sand and shale lenses was drilled from 16,735 feet to 21,050 feet (4,315 ft) using a 18.6 ppg oil based mud. Bottom hole temperature was 387° F. The whole section was drilled at an average ROP of 31.5 ft/hr while keeping the hole vertical (around 1°). The offset from the first well was drilled with two bi-center bits at an average ROP of 15 ft/hr. The bi-center bit cuased the hole angle to build more than 22°.

- **Below a PDM motor:**

A 6 ⅛" x 7 ½" EWD was run directly above a 6 ⅛" rock bit in the Gulf of Mexico, West Delta. The 6 ⅛" x 7 ⅜" ES (⅛" under gauge) was run directly above the 1.5° motor. The EWD entered the sidetrack at 31° through a milled out window. The EWD was activated and the angle was dropped to vertical while turning the azimuth 180°. At this point, a bit trip was made and the ES was changed to 6 ⅛" x 7" (½" under gauge) for rebuilding the hole angle to 55°. The whole 4,563 feet section of shale and sand was completed with only 14% sliding. (Directional Plan, Figure 4)

- **Rotary Steerable System (RSS):**

This deepwater Mississippi Canyon well in the Gulf of Mexico was sidetracking due to a loss of directional control and severe vibration problems which caused premature MWD failure. A 14 ¾" x 17 ¼" EWD was run 83 feet above a 14 ¾" PDC bit. The bit was followed by a RSS, 12 ⅛" stabilizer, LWD and MWD. The EWD followed the RSS holding angle at 38°. The 2,684 feet salt section was drilled with a flat vibration line (as measured by down hole sensors) and no MWD problems. The average ROP was 70 ft/hr from 8,481 feet to 11,165 feet. As a side note, a flip-arm underreamer was used to open the initially sidetrack hole while waiting on the BHA to reach the rig. The body of flip arm underreamer broke completely in half at the cutter arms.

Current developments

The EWD initially was a weight activated tool. A pressure activated EWD was developed one and a half years ago for underreaming an existing hole. The pressure activated EWD operates the same as the standard EWD except for initial activation. Once locked in the drilling position all flow is stopped behind the cutters and the pressure activated EWD performs exactly like the weight activated EWD.

The latest addition to the EWD is the pressure sensor tube. This gives a positive indication that the EWD is locked in the drilling position. If the EWD was to move from the drilling position for any reason, then there would be a 500-700 psi pressure drop at the surface. This would be immediately noticed by drilling personnel and the EWD would simply be relocked before drilling ahead.

The newest tool designed is the Tri Bit Reamer (TBR). This symmetrical underreamer plus bit has a short length which will help in short radius well plans

Conclusions

- Standard underreamers are a high risk choice due to the potential of breaking an arm. This option is also expensive because a separate underreaming run at slow ROP is required.
- Bi-center tools have disadvantages in directional control and slow ROP. The operating principle of pivoting on a small pilot bit to whirl the bi-center wing around and enlarge the hole often cause wellbore quality and vibration issues.
- Symmetrical underream while drilling tools place the drilling load once again on the bit (full size). This leads to faster ROPs.
- The principle of a symmetrical tool is a more uniform, steady cutting action. This increases the BHA stability and eliminates vibration tendencies. This leads to better directional control and wellbore quality. Also, longer continuous runs can be achieved as a result of less downhole tool failures.
- In the future, enlarge while drilling applications will increase as wells are drilled deeper, new technologies adopted (expandable casing) and the cost savings of advanced well planning (slim well casing plans) become mainstream.

Nomenclature

BHA= bottom hole assembly
BOP= blowout preventer
ROP= drilling rate of penetration
WOB= weight on bit
RSS= rotary steerable system
PDM= positive displacement motor
MWD= measurement while drilling
PPG= pounds per gallon
MTBF=mean time between failure
EWD= enlarge while drilling
ES= expandable stabilizer
PSI= pound per square inch

References

- Barker J.W.: “Wellbore design with reduced clearance casing between casing strings,” paper SPE/IAADC 37615 presented at SPE/IADC conference in Amsterdam, the Netherlands, 1994.
- Senger, J.: “Bi-center Bits – A Proven Method of drilling larger Diameter Boreholes,” Paper in ETCE 2001 conference in Houston, Texas, Feb 5-7, 2001
- Beaton, T. and Hudspeth, D., “Advanced Technologies Increase Hole Opening Efficiency,” paper ETCE 2001 conference in Houston, Texas, Feb 5-7, 2001

Table (1)

	Hole opening tools			
	EWD	**NBR**	**Bi-centers (SRWD, RWD, etc...)**	**Standard Underreamer**
Drill cement and shoe track then drill ahead (no trips out of the hole)	**Yes**	Yes	No*	No
Symmetrical	**Yes**	Yes	No	Yes
Directionally friendly	**Yes**	Yes (except high angle)	No	No
Relies on pressure	**No**	Yes	No	Yes
Full size pilot bit (PDC or Tricone)	**Yes**	Yes	No	Hole already drilled
Cutter Density	**High**	Low	Medium	Low
Reduces vibration	**Yes**	Yes (except high angle)	No	Sometimes
Ability to backream	**Yes**	Yes	No	No
Risk of losing cutters	**Very Low**	High	Low	Very High
Irregular hole size problems (spiral holes, egg shaped, etc...)	**No**	Sometimes in directional holes	Yes	No

*some recent products claim with minimal casing damage

Figure (1) – Enlarge While Drilling (EWD) Tool

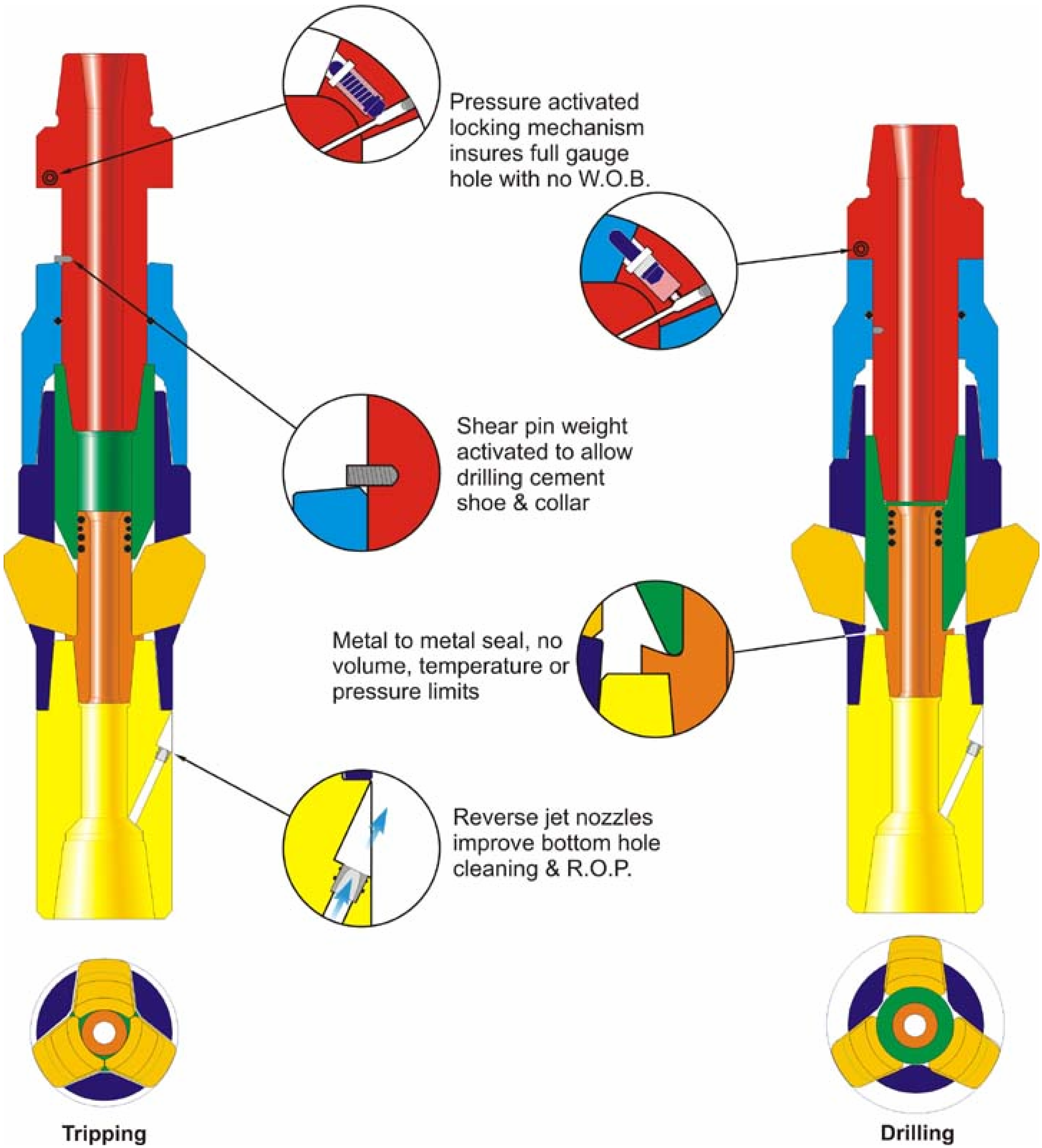

Figure (2) – EWD Activation Drawing

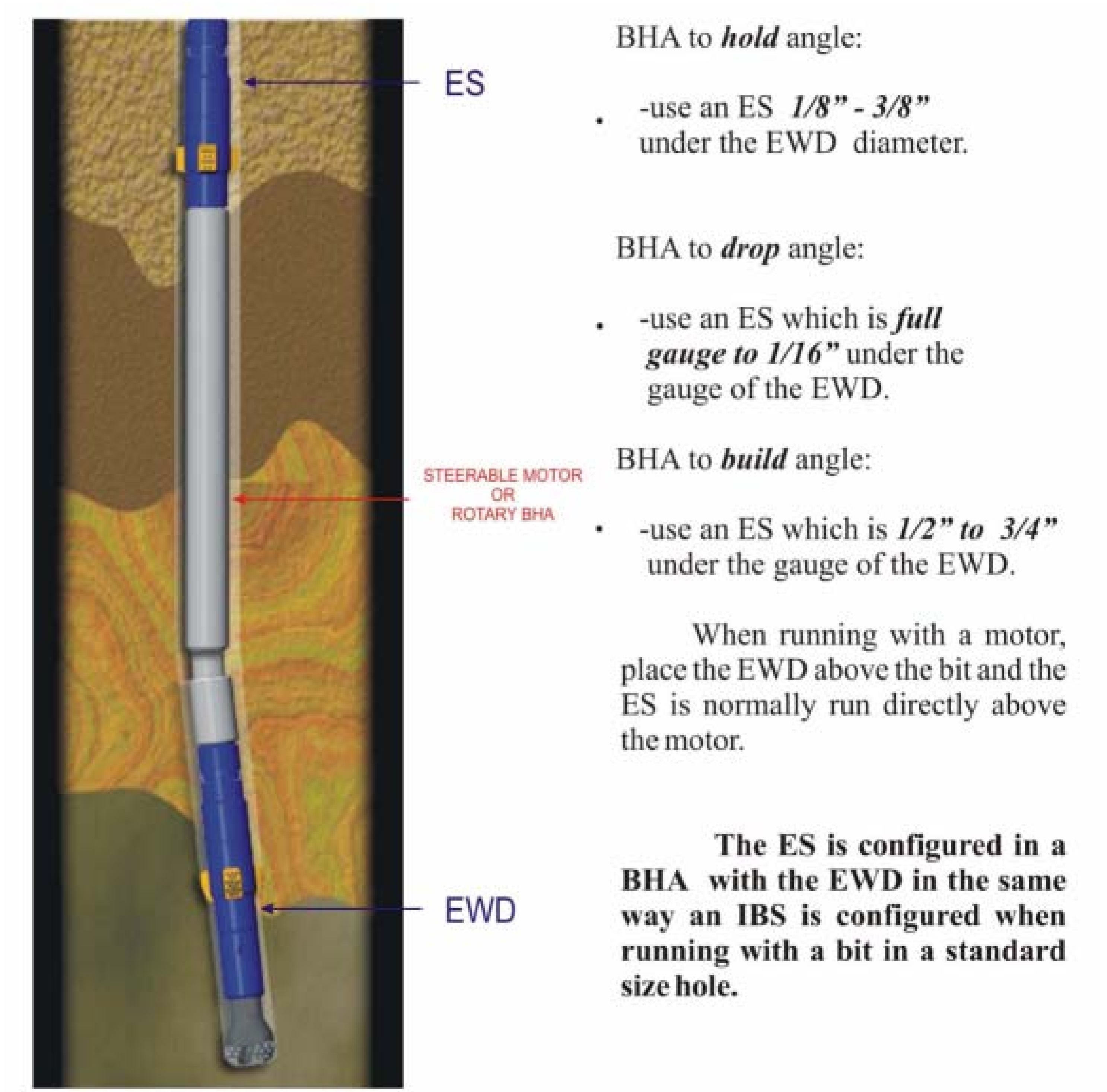

Figure (3) – Recommendations for ES Sizing

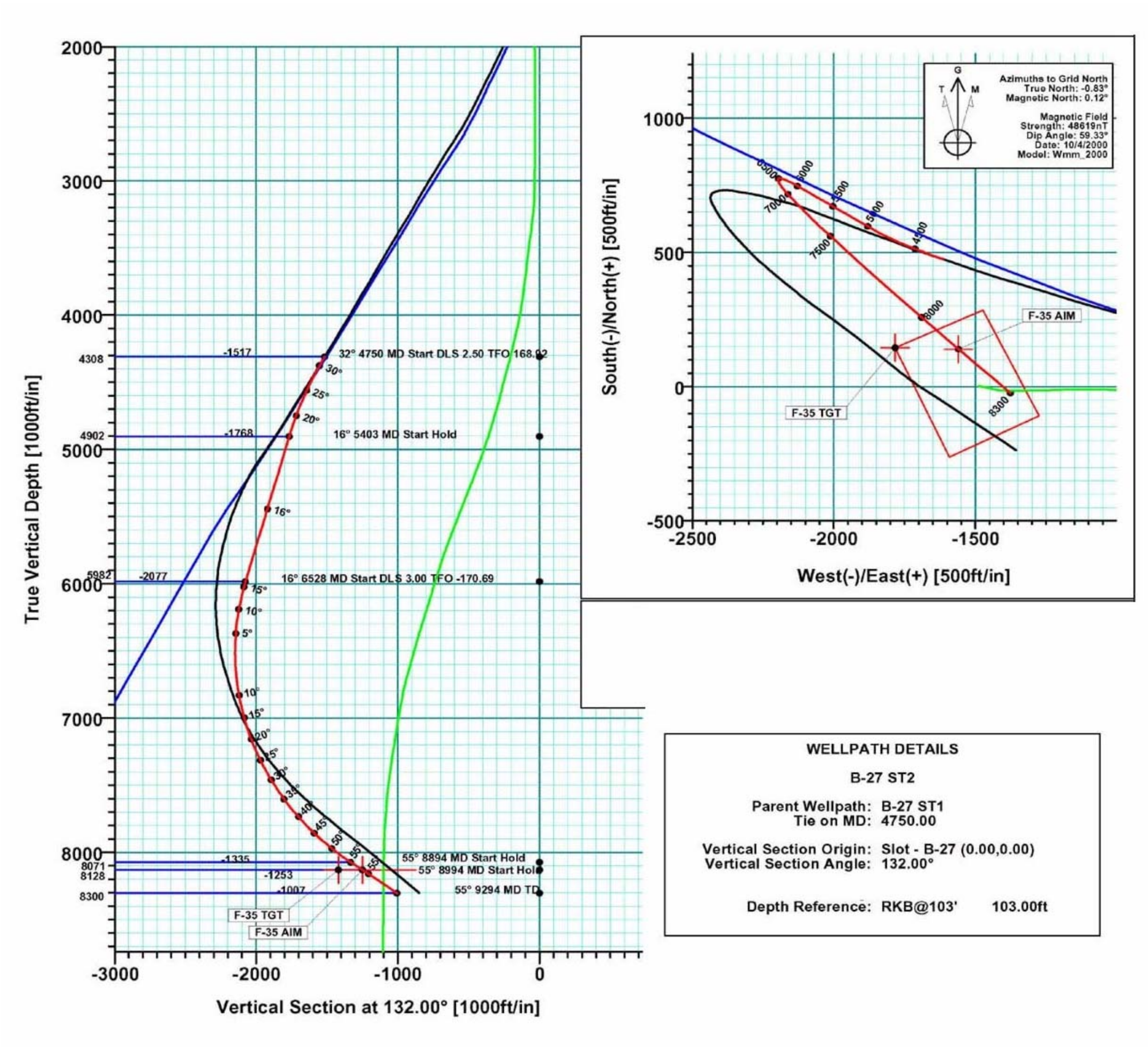

Figure (4) – EWD Below PDM Case History