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# THE NEW METHOD OF DIRECTIONAL DRILLING BY NON-ROTATING ADJUSTABLE STABILIZER

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## ABSTRACT

Directional Drilling is the process of directing the well bore along some trajectory to a predetermined target. Motivation of the early drilling of directional wells was economics and offshore field development is where majority of wells are drilling directionally 5 Defection tools is: whipstock, jetting bit, mud motor, stabilizers and turbine. The Non–Rotating Adjustable stabilizer controls curvature rate by precisely adjusting the radial extension of the stabilizer blades on a near bit Non-Rotating Stabilizer. The combination of these technologies will provide smoother bore holes, reduced drilling time, and incredible targeting precision. Tool will control curvature rates from 0 to 15 per 100 ft. in 8 1/2 inch holes with bit weights up to 55000 lb.

**Keywords:** Adjustable Stabilizer, Directional Drilling, Simulation, Oil Well Drilling

## 1. INTRODUCTION

Directional drilling can generally be defined as the science of directing a wellbore along a predetermined trajectory to intersect a designated subsurface target. It is the process of directing the well bore along some trajectory to a predetermined target. The Application of Directional Drilling is:

☑ To control vertical well trajectories
☑ To sidetrack a well
☑ To reach formation inaccessible location (city or factory, …) by vertical well
☑ Shoreline drilling
☑ Multiple wells from offshore structures
☑ Salt Dome Drilling
☑ Fault Drilling
☑ Reliep wells
☑ Multiple land wells for environmental reasons
☑ Coning (gas/water)

For example for various reasons in south Iran fields, it is not always possible to drill vertically into oil or a gas reservoir. The required bottom of the hole may be directly under a town, just off a popular beach, or under a busy lake or river. In order to drill wells under these conditions, directional drilling is needed. Using this technique it is possible to direct the hole into a relatively small target up to 7000 Ft. Away horizontally at a depth of 10.000 this method is also used to develop a field from an offshore multi-well plat from, where it is desirable to drill several wells from one location [1].

The five Defection tools are: whipstock, jetting bit, mud motor, stabilizers and turbine. The whipstock was the main deflection tool from 1930-1950. A standard whipstock is seldom used nowadays, but it has not disappeared completely. Whipstocks are used in coiled tubing drilling for re-entry work. There are 3 types of whipstock used in conventional directional drilling:

1) Standard removable Whipstock

2) Circulating Whipstock

3) Permanent Casing Whipstock.

Jetting bit (or badgering) is a technique used to deviate wellbores in soft formations. The technique was developed in the mid 1950s and superseded the use of whipstocks as the primary deflection technique. Although jetting has subsequently been supplanted by downhole motor deflection assemblies it is still used frequently and offers several advantages which makes it the preferred method in some situations. A special jet bit may be used, but it is also common practice to use a standard soft formation tri-cone bit, with one very large nozzle and two smaller ones.

A common method of deflecting wellbores is to use a downhole mud motor and a bent sub. This is placed directly above the motor and the bent sub which makes this a deflection assembly. Its lower thread (on the pin) is inclined 1° - 3° from the axis of the sub body. The bent sub acts as the pivot of a lever and the bit is pushed sideways as well as downwards. This sideways component of force at the bit gives the motor a tendency to drill a curved path, provided there is no rotation of the drill string. The degree of curvature (dogleg severity) depends on the bent sub angle and the OD of the motor, bent sub and drill collars in relation to the diameter of the hole. It also depends on the length of the motor [2].

Warren and Purdue have published timelines that show the significant industry milestones in developing directional drilling equipment [3, 4].

A solution technique for the slick one, two and multi stabilizer BHA developed by Walker and by Willheim and Apostal solve the three dimentional (3D) BHA case. Both techniques yield inclination and direction side-force components. They also handle wellbore curvature, variable gauge holds, and combination BHA components. Unlike the analytical solution these more generalized solution can handle situation in which tangency [5, 6].

The non-rotating adjustable stabilizer controls curvature rate by precisely adjusting the radial extension the stablizer blades on a near bit non-Rotating stabilizer. Figure1 is a version of the timeline s an Ing with the first positive displacement mud motor and ending with the significant goals expected to be achieved later this year. The timelines show that while we have come a long way we note that the advances were preceded by a well established need defined by the operators. Steering tools, MWD's and steerable motors were all demanded by industry well before their introduction. The same is apparent in the evolution of the rotary steerable systems. The 2-D systems were barely introduced before everyone wanted 3-D. tools. Then, when the first closed loop drill straight ahead systems were introduced we heard the calls for tools that would handle a larger share of the directional drilling operations and eventually to drill autonomously.3 The industry is already drilling conventional steerable motor sections with the straight-ahead rotary steerable tools. But, if we follow the normal evolutionary process we should not be too far away from a new generation of rotary steerable tools that are designed to control curvature rate most likely in a closed loop control process. Then in a few more years, we should expect to see equipment that will automatically drill to the directional or horizontal targets.

We expect to set the next two milestones in rotary steerable system development later this year. The Non-Rotating Adjustable Stabilizer system utilizes two revolutionary technologies. The downhole directional tool uses a patented Nonrotating Adjustable Stabilizer design that provides precise control of curvature rate. The directional drilling operations are automatically controlled by a downhole computer code called the Directional Solution (DS).This tool computes the positions of the borehole after each survey and determines the optimum three dimensional circular arc trajectories required to hit the directional and horizontal target [3, 4].

## 2. VALIDUS ROTARY STEERABLE SYSTEM

The bottom hole assembly consists of a Non-Rotating Adjustable Stabilizer. The Validus system records near bit directional surveys and transmits them to the surface through the communications link. The surface system can send changes in the target specifications or directional parameters to the NAS (Non-Rotating Adjustable Stabilizer) through the NAS system can be run with all service company's MWD or LWD systems.

Only a single BHA is needed to drill from the kickoff point or even above that depth to the total depth of a directional or horizontal well. This eliminates all of the trips required to modify the directional performance of conventional assemblies. The NAS can be run with the optimum bit, use the most effective weight and rotary speed and apply all of the available hydraulic energy to the bit.

## 3. DIRECTIONAL DRILLING CONTROL SYSTEM

The critical feature for directional drilling with a rotary steerable system is the ability to control curvature rate. The NAS controls curvature rate by precisely positioning the five individual blades on the near bit adjustable stabilizer.

The control system positions the adjustable blades to give full-gauge contact on the loaded side of the hole while providing free sliding clearances for the blades located on the non-loaded side of the hole. Utilizing five adjustable blades provides stable support regardless of the orientation of the stabilizer. The NAS utilizes a jackscrew in an inclined ramp to position each individual blade. By tracking the revolutions of each drive motor the radial positions of each blade can be controlled to within 0.0001 in.

The NAS design allows the utilization of the well established three-point geometry solution to obtain the desired curvature rates. As is shown in Figure 3 the wellbore curvature is defined by the contact between the gauge surface of bit and the hole and the contact points between the hole and the two stabilizers located immediately above the bit. The misalignment of these three contact points describes a circular arc that closely matches the curvature performance of a directional drilling assembly.

The downhole software provides closed loop control of curvature rate. It uses the difference between the planned and the actual trajectories on the most recent surveys to compute adjustment factors that will correct for the observed differences.The software uses a weighted running average process in order to rapidly respond to changes in the hole conditions while avoiding the effects of the Random survey errors. The goal of this process is to correct for the secondary effects on curvature rate caused by manufacturing tolerances, bit and tool wear, and formation effects [5, 7].

## 4. AUTONOMOUS TRAJECTORY CALCULATIONS

Circular arc trajectory equations have been available for many years. These equations provide a direct solution for calculating coordinates of a survey, but cannot be reversed to calculate the trajectory needed to hit a target. Fortunately, we discovered a direct method to calculate the required trajectory of a threedimensional circular arc from the coordinates of the target. This solution provides the basis for a directional horizontal planning program that is installed in the NAS.

The optimum directional trajectory consists of a combination of circular arcs and straight line segments. All directional targets can be intersected with a trajectory that incluCles either one or two circular arc segments. In most cases, the required trajectory is a single circular arc that may be followed by a straight tangent interval. See Figure 4.

In the remaining cases the required trajectory consists of two circular arc segments that may be separated by a straight tangent section. See Figure 5.

For horizontal targets the required trajectory is also limited to either one or two circular arc segments. For the initial landing we typically need only a single circular arc. The trajectory program requires minimal input. The user specifies the optimum and maximum curvature rates versus depth for directional targets and the optimum and maximum for horizontal targets. For directional targets we must specify the target coordinates, the target radius, and the operator's preference between adjacent targets. We also have the option of specifying the required target entry angle and azimuth. For horizontal targets we specify the coordinates of a point in the target plane, the dip angle and azimuth of the target plane and the azimuth of the horizontal section.

The simplicity of the new circular arc solution allows us to search for the optimum design. For directional wells the search process parallels the following steps:

1. The program attempts to hit up to the first three directional targets with a single circular arc trajectory and a straight tangent section, if necessary, while using the optimum curvature rates.

2- If it fails to hit any of the targets, the next step is to increase the curvature rate and repeat step one. Curvature rates are increased until the targets are either intersected or we reach the maximum allowable rates.

3- If we can't intersect all of the targets, we determine if a two circular arc trajectory will succeed. The optimum two-circular arc trajectory is found by gradually raising the kickoff point of the deeper targets. The process is continued until we intersect all the targets or find that continuing to raise the kickoff point becomes ineffective.

4- If we have been unable to intersect all of the targets we optimize a missing strategy. We use the operator's targeting preference for this step. The operator specifies if adjacent targets are of equal value or whether the upper or lower target is more valuable. If missing the less valuable target helps, we determine if we can intersect the more valuable target by missing the less valuable target by less than the specified target radius. Next we allow the preferred target to be missed by up to the specified target radius, and lastly we allow the less valuable target to land beyond the specified target radius.

5- After either identifying a trajectory that hits all of the targets or includes the optimum strategy for missing, we perform one additional optimization step.

We use the operator's specified neutral point to calculate the torque required to rotate the drill string. We determine if the torque is reduced by elevating the kickoff points of the deeper targets. We select the trajectory that produces the lowest possible torque.

The design process for horizontal targets is much simpler than for directional targets, because we are only concerned with hitting a single horizontal target specification at a time. The operator specifies the minimum, optimum and maximum curvature rates to be used in the build curve. They also specify the maximum and minimum curvature rates to be used in the dual circular arc trajectories. The design process follows the following steps:

1. Determine if we can land on the target plane using a single circular arc trajectory. If the required curvature rate is between the minimum and maximum specified, this is the solution.

2. If the single circular arc curvature rate is less than the minimum, we add a straight tangent interval above a minimum curvature rate circular arc.

3. If the required single circular arc curvature rate is greater than the maximum rate or if we can't hit the target with a single circular arc we use the two circular arc solutions. The dual circular arcs are designed using the specified optimum curvature rate.

4. If the total dogleg in the dual arc trajectory is less that the optimum curvature rate, the curvature rate is set equal to the dogleg.

The automated process allows us to utilize the smoothest possible trajectory. On conventional operations where the directional driller is required to follow the original targeting plan, each correction requires two doglegs: the first to direct the path back towards the plan and the second to realign the path with the original plan. By calculating the optimum path after each survey we limit the corrections to single and much smaller adjustments. We can also optimize the trajectories used to drill tangent sections or to track horizontal targets. We limit the size of the doglegs in these intervals by setting the curvature rate for these corrections to be numerically equal to the size of the dogleg. This spreads the corrections over 100 ft intervals and significantly reduces the influence of random survey errors.

The process becomes fully transparent to the operator. The directional program shows the operator the optimized trajectory immediately after each survey. It defines the trajectory required to land on the horizontal target or how to intersect the next three directional targets. It also defines the expected targeting precision and the curvature rates that are required. These values indicate the relative ease or difficulty we will have in hitting the targets. If the required curvature rates are at or near the specified optimum rates, we can be virtually assured of hitting the targets. However, if the required rates are close to the maximum rates there is a greater chance of encountering problems.

## 5. DIRECTIONAL DRILLING SIMULATOR& TRAJECTORY

A directional drilling simulator was developed to help us evaluate the closed loop curvature rate control system of the NAS and the autonomous trajectory planning software. The directional simulator allows us to specify the size of the curvature rate performance errors of the NAS tool and the magnitude of the random errors in the survey measurements.

The process is repeated until the well reaches total depth. The simulator defines the targeting error by interpolation for the directional targets and by computing the vertical distance between the surveys and the sloping plane of a horizontal target.

The down hole trajectory calculations are performed after each survey. Table 2 shows the calculated trajectories at the kickoff point and after penetrating each of the first three targets. At the kickoff point we need a two circular arc trajectory for the first target and single circular arc trajectory for the next two targets. After penetrating the first target, the next three trajectories are single circular arcs. However, after penetrating the second target the trajectory for the third target becomes a two circular arc trajectory. This change was produced by the rotary torque optimization routine. Simulator calculated at the kickoff point and after penetrating the first and fourth targets.

All four of the targets were intersected within a foot of the target specifications. Also includes targeting results for this directional well plan if the tool and survey error specifications are set to zero or if we double the initial error values. In both of these cases the target intersections remained within a foot of the target specifications.

The precision is especially remarkable because the formats of the error correction process are quite different than the format of the error specifications used in the simulator. The closed loop process uses a weighted running average of the differences between the curvatures calculated from the surveys and the planned curvature to produce a correction independent of curvature rate. The error simulator includes an error component that is proportional to curvature rate. The apparent independence of our targeting precision from the size of the error specification shows that our closed loop correction process is especially robust and should be expected to consistently hit directional targets within a few feet.

The last section is the targeting precision while drilling with stands and only surveying before connections. This increased the maximum error to three feet.

## 6. CONCLUSIONS

1. non-Rotating Adjustable stabilizer is very Accurated & is very economics

2. non-Rotating Adjustable stabilizer method can be drill in Ahvaz Reservoirs in Iran (Applied in multiple land wells from a Pad for environmented reasons)

3. non-Rotating Adjustable stabilizer is very exact to lnaccessible locations for example in Ahvaz field

4- The non-Rotating Adjustable stabilizer system will intersect directional targets within a few feet

5- The non-Rotating Adjustable stabilizer system will provide extraordinary tracking precision for horizontal targets.

## 7. REFERENCES

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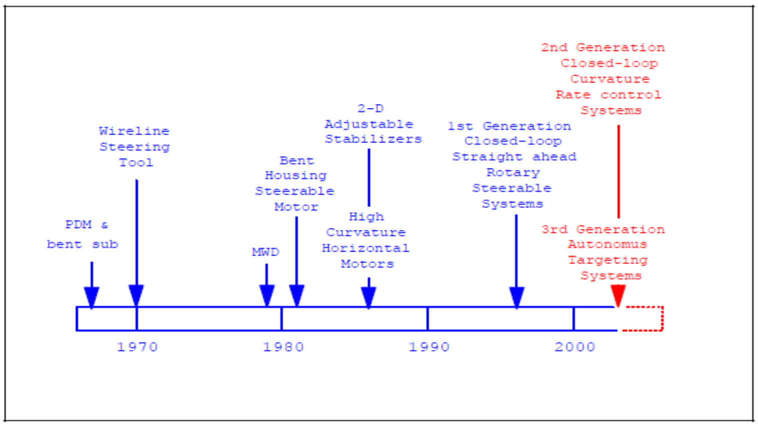


Figure 1. Directional Drilling Technology Timeline.

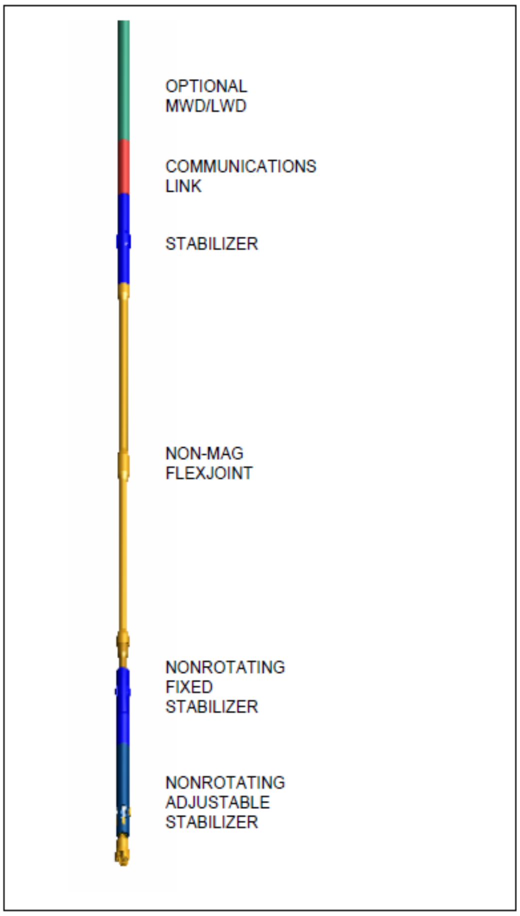


Figure 2. NAS Bottom Hole Assembly.

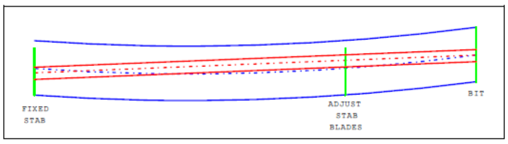


Figure 3. Three-Point Geometry Contact Points.

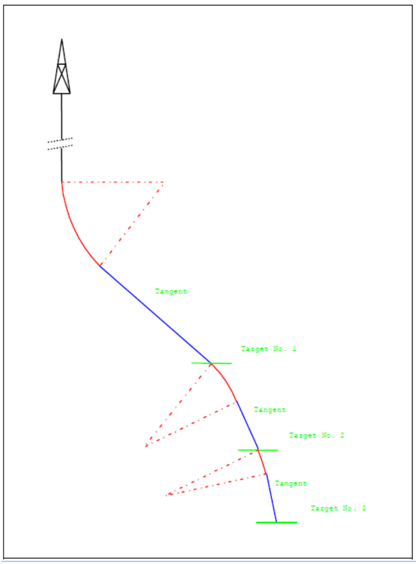

Figure 4. Single Circular Arc Trajectories.

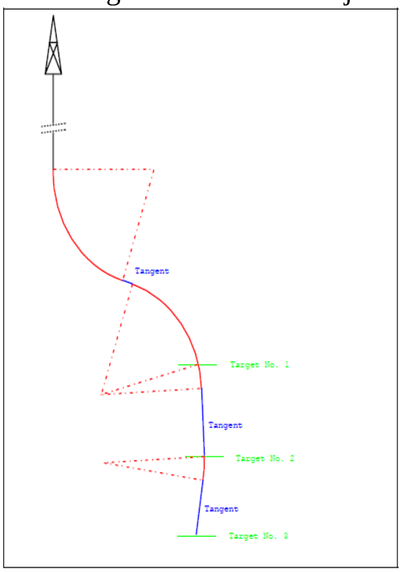

Figure 5. Two Circular Arc Trajectories.

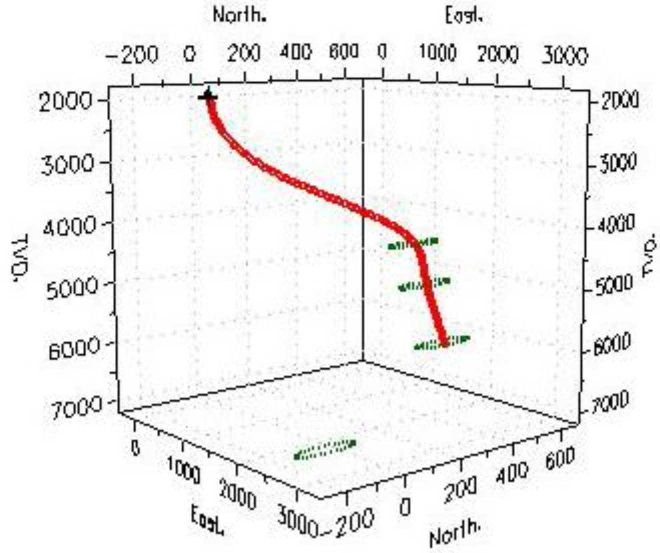


Figure 6. Four Targets Directional at the KOP.

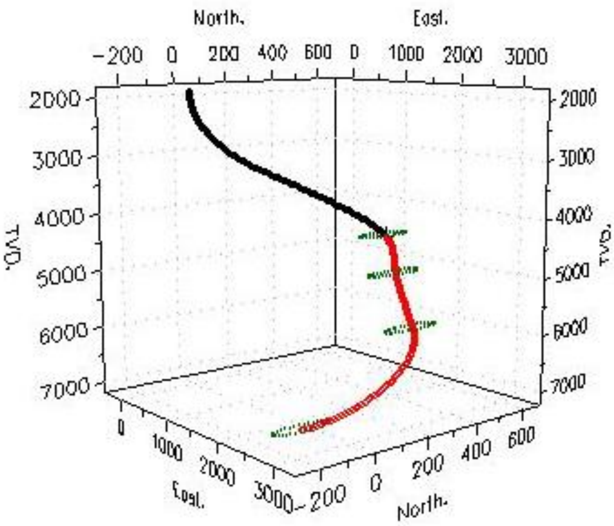


Figure 7. Four Target Directional at First Target.

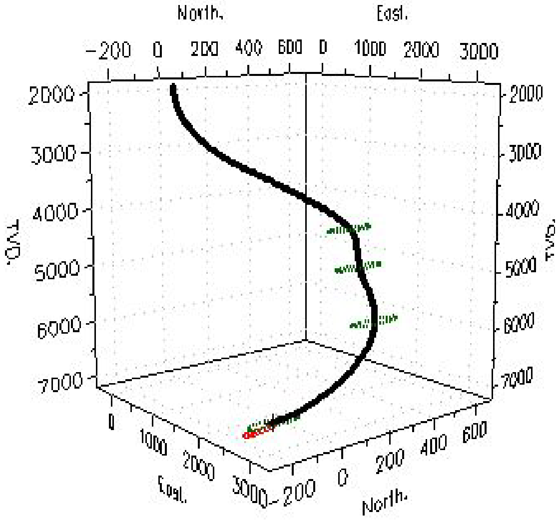


Figure 8. Four Target Directional at Total Depth.

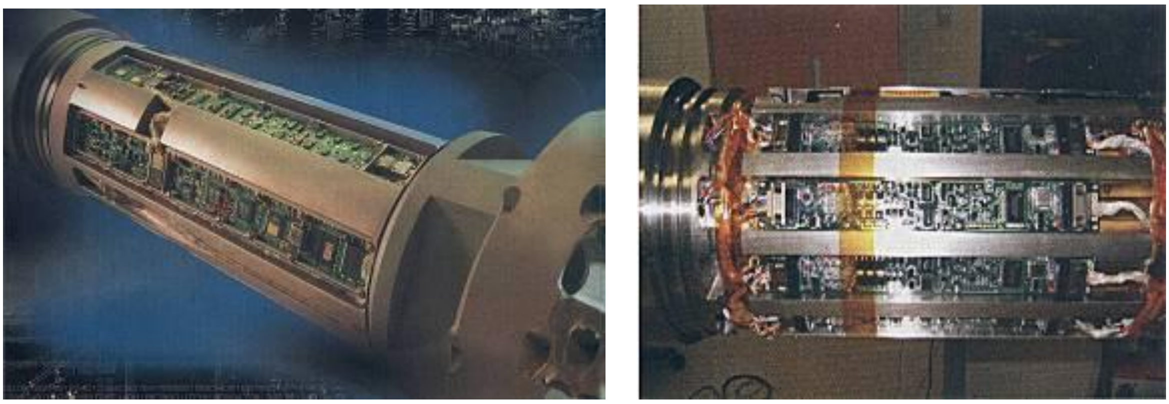

Figure11. Non–Rotating Adjustable Stabilizer.

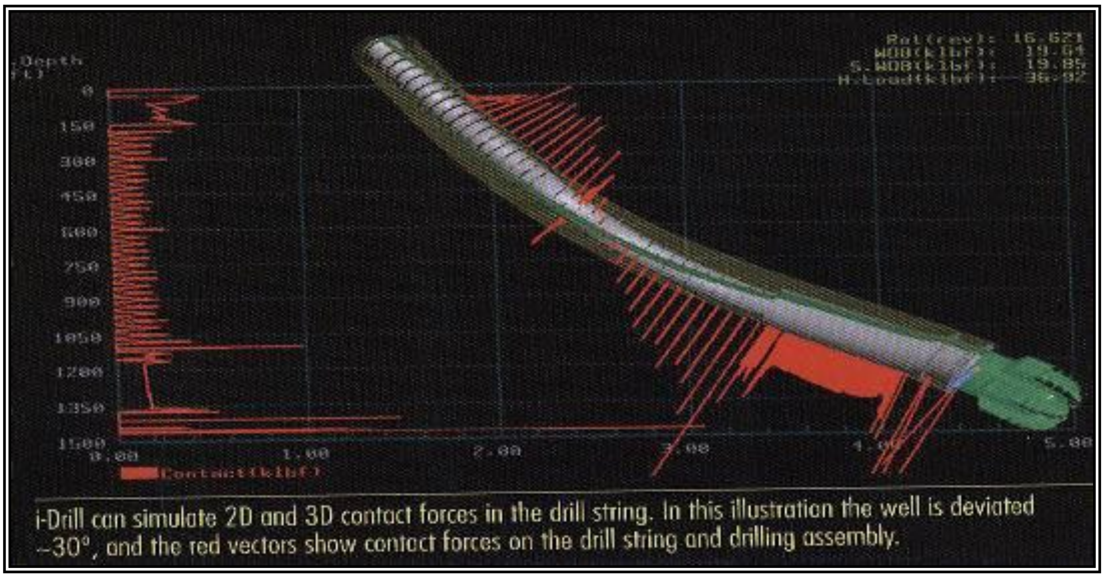


Figure 9.Contact forces on the drill string and drilling assembly

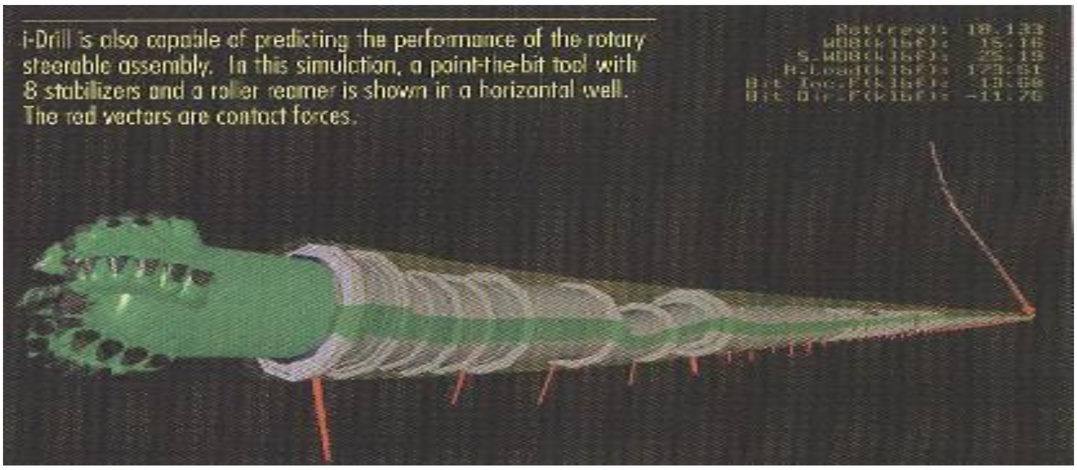


Figure 10.predicting the performance of the rotary steerable assembly