The One Trip Sidetracking System: Applications and Case Histories

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Abstract

Converging technologies this decade have provided alternative field development, depletion and drilling practices. These include horizontal drilling, geosteering and casing exit technologies. During the 1990's, the benefit of horizontal drilling was becoming evident, while milling and geosteering systems were advancing. These technologies together made sidetracking a viable remedial method.

Historically, sidetracking was used as a last resort to get around debris stuck in the wellbore or depart from a lower unproductive completion. The ability to drill horizontally geosteered wells from existing wellbores provided an economical means to recover a higher percentage of the hydrocarbons in place, and access nominal hydrocarbon reserves located behind the pipe, that otherwise could not have economically been recovered.

As milling technologies evolved through the decade, sidetracking operations became feasible in a single trip. This paper will discuss the applications, mechanics and operation of the one trip sidetracking system.

Sidetracking History

In the 1920's when whipstocks were first introduced in the fields of California, the primary use was that of a correctional device. This correction was either necessary to divert around a fish or to bring the well back to vertical. An alternate use of the whipstock was to drill relief wells in the event of a surface or underground fire. Later the tool was used to intentionally deviate the well from a vertical position. Thus, for the first time, whipstock sidetracking became a pre- planned operation and helped advance directional drilling.

During the 1920's and 1930's other methods such as knuckle joints and deflectors were used to deviate the well. All these methods were common when it was understood that geologic structures such as fault zones, stratagraphic traps, and salt domes could be directionally drilled. However, the performance of these deviation tools was not as predictable as whipstocks.

More and more, the word whipstock became synonymous with sidetracking. In the 1940's and 1950's, surveying technology advanced to provide a more accurate picture of the wells trajectory and deviation. Numerous products were developed for sidetracking during the period from 1950 to 1980. The hydraulic section mill (Figure 1) was the most noteworthy of these advances. Unlike the whipstock, the section mill removes **360** degrees of casing opposed to the smaller window provided by the whipstock. It became equally common during this period to either cut a section or mill a window.

In the 1980's hybrid carbide milling products were created and became commercially available. Typically numerous runs were needed to complete the section or to mill a useable window in the casing. By incorporating special carbides in downhole milling tools, the operational limitations changed from the mill to other rig variables such as the mud and pumps. Now the section mill could remove up to 100 feet in a single run at a very rapid milling rate. However, the metal cuttings from this operation have to be removed from the wellbore in a timely manner to prevent sticking of the milling assembly, thus the milling rate must be controlled to prevent problems. Once the section is cut, a cement plug must be set and allowed to harden to provide the platform for the well to be sidetracked. These cumulative operations are time consuming and impact the overall economics of the re-entry operation.

At this time whipstock technology had not progressed as rapidly as section milling. **So** it became very common in the late 1980's and early 1990's to mill a section to sidetrack the well. Operators were quite comfortable with this method and confident the well would be directionally drilled in a predictable amount of time. During this period the major service companies undertook individual projects in order to make the whipstock a viable alternative to section milling.

If the number of runs to mill a window could be reduced, the whipstock would provide a faster means of exiting the well and accelerate the drilling objectives. In addition, eliminating the required cement plug and the necessity of circulating large amounts of steel cuttings out of the well would further reduce the time and cost associated with section milling. However, most whipstocks required from three to five trips in order to set the whipstock anchor, mill the casing, pull out of the hole and provide a useable window to accomplish the drilling objectives. (Figure 2) The number of required trips combined with past unpredictable whipstock/mill performance made these systems economically prohibitive in most cases.

The 1990's marked continual improvements in whipstock technology. By the mid part of the decade, the number of trips to complete a window had been reduced to one. (Figure 3) Equally important was the reduced risk associated with whipstock operations. Today the preferred method for re-entry is the whipstock, with the section mill coming in a distant second.

Sidetracking Applications

Prior to advancements in sidetracking it was standard practice to clean the existing wellbore and recomplete when production rates declined. If production was enhanced at all, it was generally short lived. Inherently, these practices were unsuccessful due to the constraints placed within the wellbore when it was originally drilled and completed. Meaning production was a function of the damage incurred during the original drilling and completion process that often could not be overcome within the constraints of that wellbore. And when these obstacles were overcome using stimulation or fracturing technology, the limitations of sweep efficiencies within the reservoir still existed. Thus, much of the hydrocarbons were left in place as bypassed production. To tap the remaining hydrocarbons, if deemed economical, expensive infill drilling programs ensued.

Sidetracking provides many benefits to economically recovering more of the original oil in place, often at accelerated rates. These include:

- Elimination of original wellbore problems,
- Minimization of the amount of new hole to be drilled versus a new well,
- Utilization of existing infrastructure,
- Implementation of the latest fluids technology,
- Capitalization on advanced directional/horizontal drilling practices,

- Exploitation of existing reservoir boundaries (3D Seismic) and other recoverable reservoirs behind pipe,
- Multilateral technology.

Design and Development

The first issue to be addressed was identification of the variables involved in milling a window. These included:

- Whipstock design,
- Milling assembly design,
- Anchor types.

The whipstock design needed to insure a more expedient cut out through the casing during milling. Performance of the milling assemblies needed to be consistent and capable of completing the window in one run. Anchoring devices needed to be capable of providing the necessary options based on the wellbore's long term objective.

Through FEA (Finite Element Analysis) and BHA (Bottom Hole Assembly) modeling it was apparent that a properly designed mill could accomplish the objectives set forth in a One Trip System. These included:

- Setting the anchor,
- Shearing off the whipstock,
- Initial cutout of the casing,
- Elongation of the window,
- Gauging the window,
- And drilling the desired rathole.

Discussion of the One Trip System will be broken into four major components:

- The Hydraulic Multi-Cycle Valve,
- The Running Tool,
- The Milling Assembly,
- The One Trip Whipstock Assembly.

The Hydraulic Multi-Cycle Valve (HMCV) performs several functions in the system. It allows the drill pipe to fill while running in the hole and permits the whipstock assembly to be oriented using MWD (Measurement While Drilling). If orienting with a gyro, the HMCV allows the gyro to be pumped down. Whichever method of orientation is utilized, the hydraulic anchor is isolated. After establishing orientation the valve is closed to facilitate setting of the hydraulic anchor. The HMCV can be re-opened to verify orientation prior to milling if desired or can remain closed allowing the drilling fluid to be directed to the milling assembly for cooling and cutting transportation.

The Running Tool provides a barrier between the drilling fluid and the fluid in the whipstock assembly, insuring that the hydraulic setting mechanism stays clean. For mechanically set anchors the Running tool is not required.

The Milling Assembly is an exclusive component with three full gauge mills. The Lead Mill is designed to initiate the cut through the casing, mill a full gauge window, and drill a full gauge rathole. The Follow Mill elongates the window and the Dress Mill smoothes and gauges the window from top to bottom.

The One Trip Whipstock Assembly consists of the whipstock and anchor. Design of the whipstock was achieved in conjunction with the milling assembly. The accelerator ramp on the whipstock top provides a quick cutout. A mid ramp pushes the milling assembly past center point over a minimal distance and eliminates such problems as coring the center of the mill and/or milling of the whipstock face.

A variety of anchors may be run on the bottom of the whipstock depending on the drilling and completion objectives. Anchors can be mechanical or hydraulic set and retrievable or permanent.

Case Histories

Since 1996 there have been hundreds of One Trip Whipstock Systems run around the world. These have been run in casing sizes ranging from 4-1/2" to 13-3/8", run to depths greater than 21,000 ft., and in deviations up to 92 degrees.

In a comparison of whipstock jobs performed with the One Trip System versus conventional systems, the following conclusions can be made:

- The milling efficiency of the one trip sidetracking system is greater than that of the conventional systems.
- Comparing strictly milling time, 81% of the one trip system completed milling operations in less than eight hours.
- 46.5% of the conventional sidetrack systems completed milling operations in less than eight hours.

Note: these numbers do no reflect the time required for tripping in and out of the hole.

Conclusions

The evolution of sidetracking dates back to the early 1900's, where the equipment to perform this work was crude and used simply as an alternative to going around a fish in the wellbore or to correct the direction of a hole. These applications were for wells being initially drilled. By the 1970's sidetracking tools had progressed to being utilized for re-entry applications as an alternative to recompleting the well. However, these operations still carried a significant amount of risk and were time consuming.

Technological advancements in carbide cutting structures in the 1980's made these operations less **risky** and more predictable. It was during this era that section milling became the most common method of sidetracking. By the early 1990's whipstock anchoring and deflection equipment evolved to meet the advancements in cutting structures. The advent of a One Trip Sidetracking System has propelled window cutting back to the forefront of re-entry operations. What was once an unpredictable, time consuming process is now accomplished in a minimal amount of time with very predictable results. In a single trip in the hole, all seven steps necessary to provide a useable window can be accomplished. This has driven costs down and made it feasible to implement this technology in a variety of different applications.

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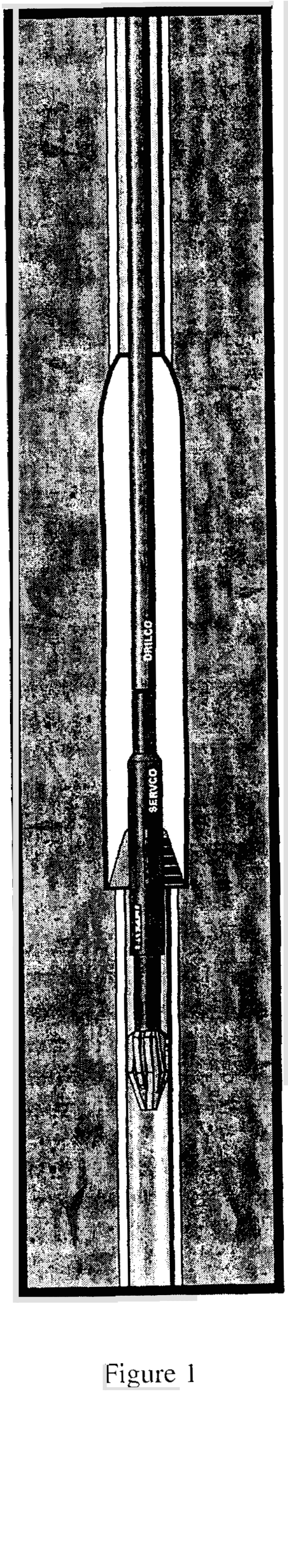

Figure 1

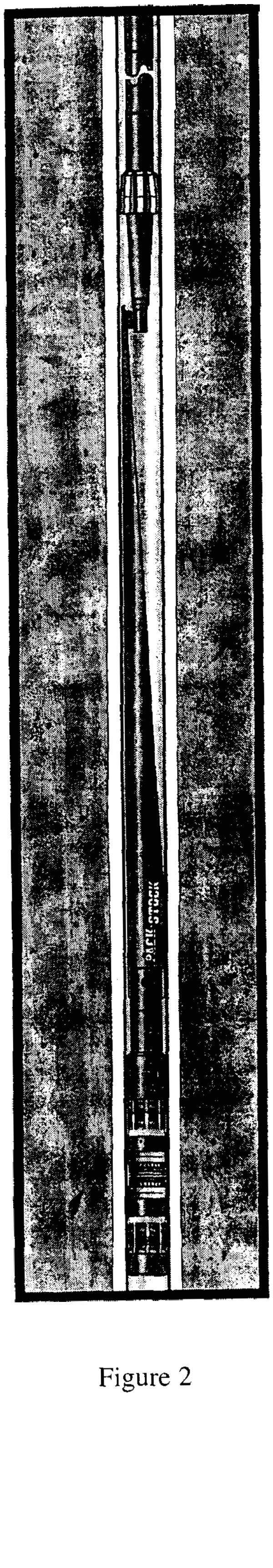

Figure 2

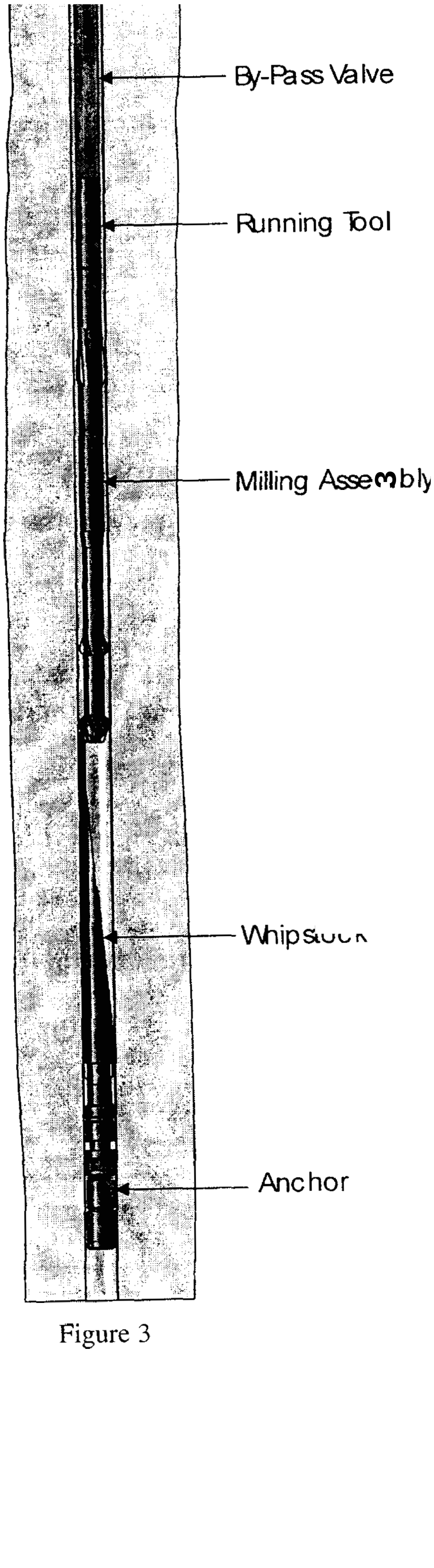

Figure 3