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DRILLING MULTIPLE LEG GEOTHERMAL WELLS USING RETRIEVABLE CASING WHIPSTOCKS

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ABSTRACT

This paper describes a retrievable casing whipstock system developed by Baker Oil Tools for geothermal applications. The following discussion compare the conventional cement plug kickoff method and the retrievable whipstock system. A case history of the first geothermal well using a retrievable whipstock system is also presented.

INTRODUCTION

Since the late 1980's, many multiple leg geothermal completions have been successfully completed. Improved drilling techniques and technologies have made this type of completion more economically and increased the amount of steam which may be produced from a single wellbore.

The conventional method of drilling a secondary leg is known as "sidetracking". Sidetracking involves milling a casing "window" (i.e., completely removing a section of casing). Removing the casing permits drilling out the window and through formation toward a desired target and facilitates a separate, individual producing leg.

Milling the window begins by isolating any drilled legs that are below the casing window depth. This is accomplished by setting a retrievable bridge plug with a column of sand placed on top. A thirty-five to forty-foot window is then milled in the casing. After removing the casing, a bit and string mill assembly are run to "dress off" the casing. This further removes metal cuttings and residual debris that can collect as a result of the milling process.

The milltrack method of sidetracking involves placing a high compressive strength cement plug in the casing across the window after milling has been completed. Placement of the cement plug requires a "waiting on cement" time of up to twenty-four hours. A drilling motor and bent sub are then utilized to initiate the sidetrack leg or new hole.

An inherent risk when sidetracking off a cement plug is that the plug may degrade from the effects of continual contact with stiff drilling assemblies or simply lose its bond to the casing. When this occurs, there is suddenly no longer a whipstock providing the lateral forces required to make the drilling assembly enter the newly drilled hole. Drilling continues in the leg until loss of circulation indicates crossing a fracture which typically would produce steam. The hole is then blown dry with air, and drilling continues with air. Placement of a new cement plug should the original plug be lost will be difficult at this stage because of steam entry and loss of circulation.

RE-ENTERING THE CASED LEG

Attempting to re-enter the cased wellbore (cased leg) can present many problems. To re-enter the cased leg, an ultra-stiff drilling assembly is used to "time drill". Time drilling is a technique of limiting penetration rate to remove the cement from the casing without allowing the bit to migrate into the window. If the drilling assembly does not precisely re-enter the lower casing stub created by the window milling process, additional trips with bits or tapered mills may be required to attempt to produce a funneled entry into the lower stub.

These additional trips can become very costly. If the casing stub is successfully re-entered, the bridge plug must be retrieved to allow steam production through the casing stub. These time-consuming and risky operations make the utilization of the Baker Oil Tools Retrievable Casing Whipstock system economically and operationally viable for geothermal wells.

TOOL EVOLUTION

Conventional permanent casing whipstocks are utilized in oil and gas applications to sidetrack and kick off drilling operations in existing wellbores. Permanent whipstocks have a major disadvantage in geothermal applications of not allowing the legs below the whipstock anchor to be produced. Production from below is prevented because of the sealing characteristics of the whipstock anchor and its permanent nature.

Recent innovations, however, allow for tool retrieval upon completion of drilling in the sidetrack leg. Retrievable whipstocks provide a mechanical means to exit the casing or mill a window, without the disadvantages of the cement plug method (i.e., placing the plug, wait on cement time, possible degradation problems, etc.).

Retrievable whipstock sidetracking is begun off the face of the whipstock, and a window is milled only in one side of the casing. Once the whipstock is successfully retrieved, the casing remains integral. This eliminates the casing stub re-entry problems previously discussed and greatly reduces the risks associated with multiple completions. The retrievable whipstock system allows many secondary legs to be drilled from an existing cased wellbore.

TOOL DESCRIPTION

Baker Oil Tools Retrievable Whipstock system consists of four major components: 1) whipstock mills; 2) outer whipstock housing; 3) inner whipstock; and, 4) retrievable whipstock anchor packer.

WHIPSTOCK MILLS

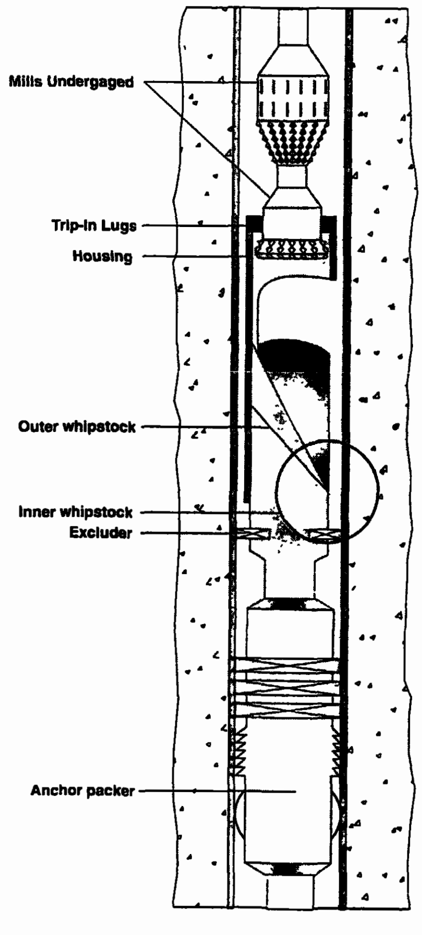
Mills used in this system include an undergage window starting mill; an undergage string mill, followed on a subsequent trip with a full gage taper mill; string mill and watermelon mill. The undergage window starting mill is a patented Baker design utilizing patented METAL MUNCHER carbide technology. Its undergage size is a function of the setting mechanism which will be discussed later in this paper.

The starting mill is followed in the drill string by an undergage string mill. The string mill is dressed with Superloy carbide chips.

The other mills used in subsequent runs are full-gage taper mill, string mill and watermelon mill. These mills are dressed with Superloy carbide chips. They follow the undergage mills and produce a final surface finish and dimension equal to or greater than the drift of the casing.

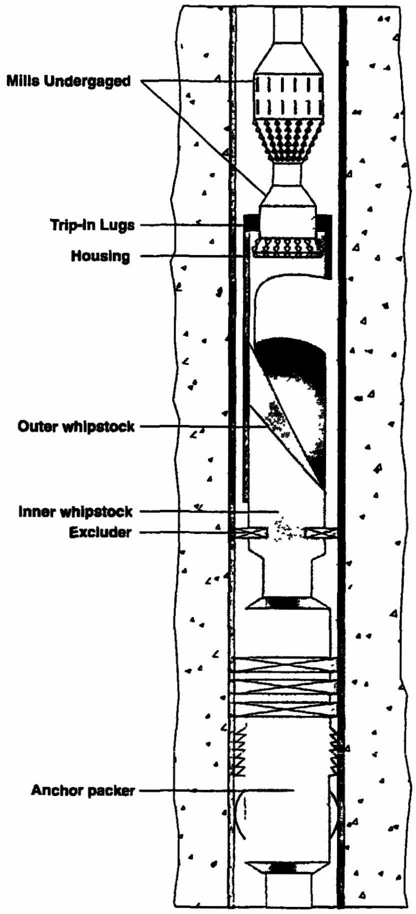
OUTER HOUSING

The outer housing is an integral part of the Baker Retrievable Whipstock System. This housing surrounds the inner whipstock and has the whipstock slide face welded into it. The outer housing permits the carry in of the entire assembly (undergage mills, whipstock, and anchor) on the initial trip as shown in Figure 1.



Fig#1-Retr.Whipstock

After setting the anchor assembly, the mills are sheared from the outer housing and permitted to proceed down the whipstock face to cut the window. After the undergage window is completed and the undergage string mill has been passed through the window, the mills are pulled from the well. The outer housing is now retrieved with a conventional casing spear. Removal of the outer housing and the integral whipstock slide face leaves a short 15 degrees whipstock (inner whipstock) looking up. The point in the casing at which the primary whipstock angle and the inner whipstock angle intersect the casing are identical as shown in Figure 1A. This prevents re-entry problems caused by hitting lips or ledges in the window.



Fig#1-A-Retr.Whipstock

INNER WHIPSTOCK

The inner whipstock provides the necessary mechanical advantage to direct the drilling assembly out the window. It also provides an OD which can be washed over and recovered with conventional fishing tools during the retrieval process. A feature unique to the Baker system is the bypass flow area provided through the inner whipstock assembly. This bypass allows steam from the cased leg to continually vent upward through the inner whipstock, preventing pressure buildup below the anchor. An integral check valve prevents contamination below the anchor by the drilling fluids.

ANCHOR ASSEMBLY

Baker offers retrievable anchors with two setting methods, off bottom or bottom set. The off bottom anchor requires at least 360 degrees of rotation at the tool to release the setting mechanism. The bottom set anchor actuates when the tool encounters weight via contact with a cement or retrievable plug.

The geothermal anchor packer is designed to fix the whipstock orientation and to pressure isolate the lower casing from the upper casing. The anchor assembly incorporates patented FLEX-LOCK slip technology. The FLEX-LOCK slip prevents rotation or vertical movement of the anchor assembly. The slip incorporates carbide inserts into a solid piece design to ensure positive casing engagement. Distribution of slip load is transferred by slip/seat bearing surfaces. This circumferentially distributes the slip load to the slip seat.

At rated load capacities, the anchor will cause no plastic deformation of the pipe in which it is set. Load capacity ratings for the 9-5/8" and 13-3/8" anchors are 625,000 lbs and 1,275,000 lbs, respectively.

Available elastomer technology allows the geothermal anchor packer to withstand temperatures in excess of 650°F. The anchor can be straight pull released with a pre-determined shear value that is job specific.

GENERIC OPERATIONAL PROCEDURE

Prior to picking up the retrievable whipstock system on the rig, the inner whipstock is installed inside the lower section of the outer whipstock housing. The outer whipstock housing is shear pinned with approximately 40,000 lbs to the inner whipstock assembly. These two units when assembled are referred to as the upper whipstock assembly.

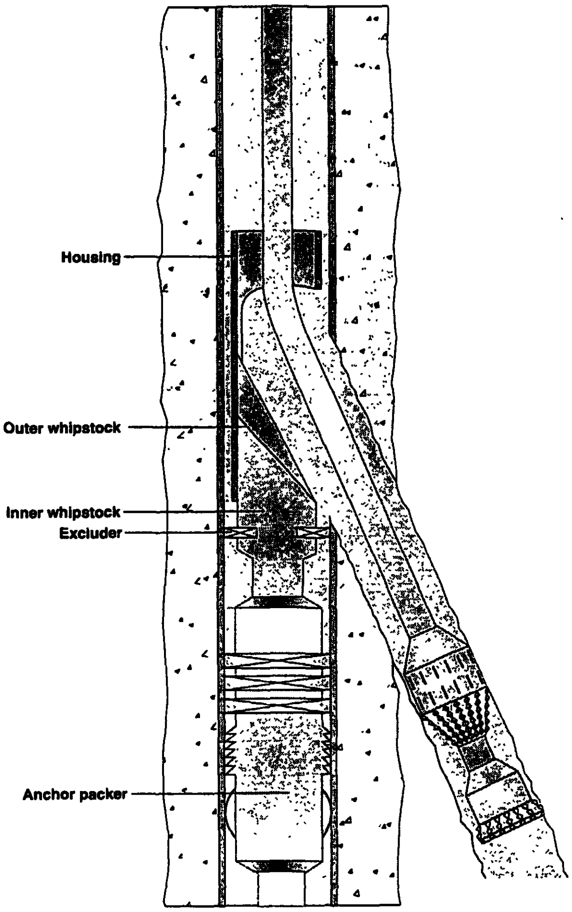
The undergage window starting and undergage string mill are installed in the upper section of the whipstock housing. These are shear pinned in place through two mild steel lugs with 60,000 lbs The whipstock anchor is shear pinned for the job's specific predetermined value.

The upper whipstock assembly and whipstock anchor are made up on the rig floor. Above the undergage string mill is one drill collar and an orienting sub. The sub is oriented to the whipstock tool face. If a bottom set anchor is utilized, an artificial bottom must have been previously placed in the casing at the appropriate depth.

The whipstock assembly is tripped in the well to the desired window depth. Once setting depth is reached, several turns of right-hand rotation position the setting mechanism of the off bottom set anchor for final setting.

The whipstock face must be oriented prior to applying set-down weight and fully setting the anchor. Once tool face direction is determined, rotation is applied to the drill string for proper orientation. Set-down weight of approximately 40,000 lbs engages body lock ring and sets anchor. Additional set-down weight of 60,000 lbs releases the mills from the mild steel lugs in the outer housing.

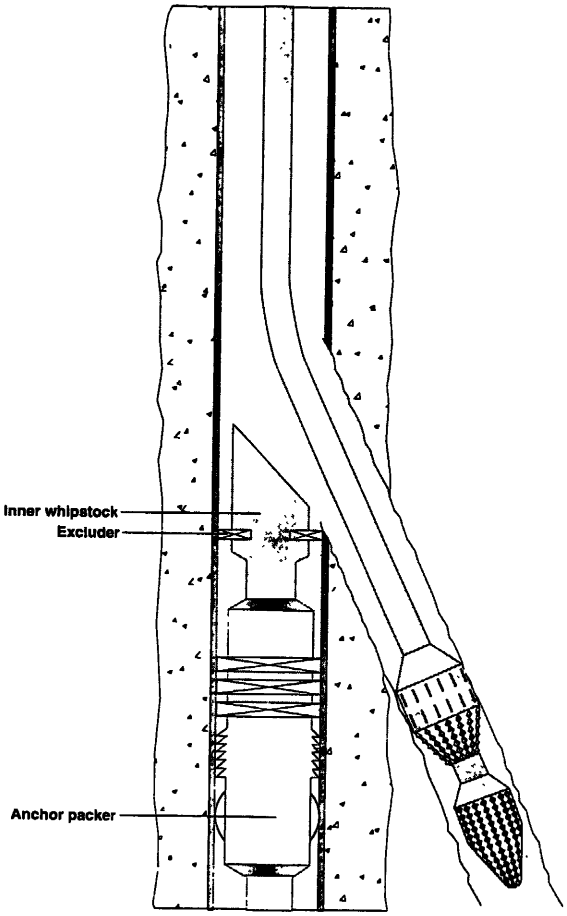
Circulation is started and rotation commenced. The string mill now removes the mild steel lug from the housing. Once the lugs are removed, the window starting mill is free to travel down the whipstock face and begin milling the window. The window is cut and the undergage string mill passed through the window as shown in Figure 2. This BHA is now removed from the well.



Fig#2-Retr.Whipstock

A conventional internal casing spear and bumper sub is picked up and made up to the drill string. This assembly is tripped in the hole to the top of the outer housing. The spear and outer housing are engaged. Approximately 40,000 lbs over string weight is pulled, shearing the outer housing from the inner whipstock. The outer housing is removed from the wellbore.

A BHA of full gage mills including a taper mill, string mill, one drill collar and a watermelon mill and the remaining collars are required to provide sufficient milling weight. This assembly is tripped to the window and milling is commenced as shown in Figure 3.



Fig#3-Retr.Whipstock

This BHA enlarges the undergage opening to full gage, elongates the initial window, and provides a smooth transition from the original cased wellbore into the new leg. The BHA is now removed from the well.

At this point, drilling of the new leg may continue per the operator's requirements. Upon completion of the drilling operations and removal of the conventional drilling assembly, the leg may be completed via openhole or cased hole options.

The Baker system offers the advantage of leaving the top of the liner from the new leg inside the original cased leg for later removal. The method that is utilized to recover the inner whipstock and anchor will allow cementing of the liner into the main cased wellbore.

A conventional rotary shoe is run to remove all drill cuttings and debris from the top of the inner whipstock to the excluder ring. This provides a uniform surface for the subsequent overshot to engage. The pressure from below the anchor is equalized, and thus surge conditions do not exist when removing this anchor from the well. Tension is applied to the drill string to overcome the predetermined shear in the anchor assembly. The inner whipstock and anchor assembly are removed from the well.

CASE HISTORY

The following case history describes the first retrievable whipstock assembly utilized in a geothermal application. The well was located in Nevada in the Fish Lake Geothermal Field. Redhill Geothermal was the operator of the F.L.P.C. #31-13 well. The sidetracking operations were commenced on July 1, 1993. The objective was to drill another leg because of poor steam production from a single leg.

The well was completed with 13-3/8" 54 lb/ft N-80 surface casing to a depth of 2498'. The well had a 9-5/8" 40 lb/ft liner from 2195' to 3843'. The well was completed with an 8-3/4" open hole.

The Baker 9-5/8" Retrievable Whipstock designed to be set off bottom was picked up and run in the hole to a setting depth of 3629'. The shear release had been preset with 80,000 lbs prior to running the tool. The drill string was rotated approximately five turns to release the setting mechanism into the set position. An Eastman Seeker Gyro was used to check tool face orientation.

The string was rotated to position tool face at 145 degrees from North, which was the operator specified azimuth. The string was lowered, and 40,000 lbs of slackoff was applied to the tool. This set and packed off the anchor. Another orientation run was made to confirm that there was no movement during the setting procedure. The tool face was found to be at 140 degrees from North, or a five degrees loss in azimuth. The operator agreed that this was acceptable.

The string was slacked off an additional 20,000 lbs (a total of 60,000 lbs) and a shear was noted. This shear was the undergaged mills (dressed to 7-1/2") moving downward, releasing from the lugs in the outer housing.

Drilling mud was placed in the well for milling operations. The string was lowered until the string mill contacted the lugs. The lugs were milled in five minutes using 2-3000 lbs and 80-100 RPM. The string was lowered until the window starting mill contacted the wall of the casing.

Milling of the window started at 3629' using 80-100 RPM and 5-8000 lbs weight. The window cutting operation took approximately five hours with the bottom of the window at 3641'. The window was cut at an average milling rate of 2.4 ft/hr. An additional three hours were needed to drill 8 feet of open hole to 3649' and ream the window.

The hole was circulated clean, and the undergage BHA was removed from the well. A 6" fishing bumper sub and an 8-5/8" internal casing spear designed to catch the 7-5/8" ID of the outer housing were picked up and run in the well The spear was engaged into the outer housing. Approximately 40,000 lbs of tension was pulled into the drill string, and a shear was noted. This shear was the release of the outer housing from the inner whipstock.

The outer housing was removed from the well and laid down. A 2' taper mill, 7' string mill, 1-10' x 4-1/2" pup joint, a 7' watermelon mill, and six joints of 6" OD drill collars were picked up. The mills were dressed to 8-1/2" OD. This BHA was tripped into the well to 3636'.

Reaming of the window was commenced and progressed from 3636' to 3649' in 2 hours The hole was circulated clean, and this BHA was tripped out of the hole.

At this point we were released from the well, so operations carried out by the operator to drill the sidetrack leg are not detailed. The operator had drilled to approximately 3850' MD. During their drilling operation, they experienced a twist off in their drill pipe. An overshot was picked up to recover the fish. The fish was recovered and tripped to surface. While handling at surface, the fish was inadvertently released from the overshot and fell into the wellbore. The fishing assembly was tripped in the hole again to recover the drill pipe fish. There were surface indications that the fish had been swallowed. Approximately 100,000 lbs tension was pulled and the fish came free. The drill pipe was removed from the well. The fish that was actually recovered was the inner whipstock and anchor assembly.

A casing inspection log was run to determine if the impact of the fish on the retrievable whipstock assembly had caused any casing damage. The log indicated no damage or ID change in the area where the anchor had been set.

The anchor was visually inspected and initially thought to be in good condition for rerun. Upon rerunning the anchor, we were unable to make it set. The anchor was then subjected to a tolerance study, and it was determined that the slip ramp was slightly deformed. The deformation was so slight that the slips could be traveled on surface; however, when confined in the casing would not fully extend. This was a direct result of the impact of the fish hitting the whipstock.

The prototype nature of this tool precluded any backup parts for immediate replacement of the anchor. As a potential solution, Baker suggested to the operator that we could modify a Baker Model "D" Hanger Packer to hold the whipstock and provide the necessary packoff.

This option had several risks associated with it since the Model "D" was not originally designed for this application. These risks were that the Model "D" would be potentially permanent and was not designed to resist rotation. The operator elected to accept this solution since the window had been cut and the forces involved would be lateral to kick the drilling assembly out the window, not rotational. The low production rates from the lower cased leg made the possible loss of steam from this leg, if the Model "D" could not be retrieved, acceptable.

The upper assembly, which included the Model "D" as an anchor, the inner whipstock, outer housing and undergage mills as before was picked up. The whipstock was oriented and set. The window was reamed to repair the damage caused as the fish had exited. Upon completion of the cleanup of the window, the operator picked up an overshot to attempt to recover the original fish. The fish was found to be on bottom at the end of the leg and deemed unrecoverable. It was decided to sidetrack off the top of the fish, and the leg was completed. The drilling assembly was tripped out of the hole and laid down.

Baker utilized a rotary shoe to dress the OD of the inner whipstock to 7" OD. An overshot and jars were tripped in the hole to the inner whipstock and engaged. Approximately 70,000 lbs tension was pulled to release the Model "D" Hanger Packer. Use of jars was not required. The assembly was removed from the well and both legs successfully comingled.

CONCLUSIONS

The Baker Retrievable Whipstock System functioned as designed for setting, recovering the outer housing, and releasing and removal from the well. The tool continued to function even after being subjected to a severe impact load. The FLEX-LOCK slips in the anchor didn't induce any subsequent damage to the casing as a result of the impact. The system proved to be an economically viable alternative to the conventional cement plug sidetracking method.

ACKNOWLEDGMENTS

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REFERENCES

1. Yarter, Richard E., Cavote, Paul E., and Quinn, Don G. (1989), *Forked Wellbore Completions Improve Development Strategy*, Geothermal Resources Council, Transactions, Volume 13.

2. Steffen, Marc W., *Designing and Drilling Multiple Leg Completions in the Geysers*, Geothermal Resources Council, Transactions, Volume 17, Oct. 1993.