Aerated fluids drilling used in Philippines field to minimize well interference while infill drilling

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THREE WELLS IN the Leyte Geothermal Production Field (LGPF) were drilled by the **Philippine National Oil Company – Energy Development Corporation** (PNOC-EDC) and **Weatherford International** using aerated drilling fluids. The aim was to determine the technology's feasibility in terms of minimizing, if not eliminating, well interference while conducting infill drilling within shallow to intermediate depths in an actively producing two-phase zone of a geothermal reservoir. The results of a well interference monitoring program reveal that aerated fluids drilling technology is capable of minimizing well interference during infill drilling in a geothermal reservoir.

INTRODUCTION

The LGPF is the largest wet steam field in the world and home to the world's single largest power station — the 232.5 MW Malitbog geothermal power plant. Given the fact that LGPF has been producing since 1983, most of the replacement wells are drilled infill, which means they are located within the same reservoir and near existing wells. Drilling problems encountered related to interference with actively producing wells prompted PNOC-EDC to experiment with the utilization of aerated fluids. Using Weatherford underbalanced systems, three new wells were drilled in LGPF.

Well interference during infill drilling was observed when two wells being drilled in LGPF adversely affected the performance of two actively producing wells in their immediate vicinity. The drilling of well 313D affected 307D, while drilling operations for well 419D interfered with the performance of well 409D. Wells 313D and 307D are located in the Malitbog-South Sambaloran sector, while wells 409D and 419D are in the Upper Mahiao sector of LGPF.

Well 307D was a production well that was producing 6 MWe as of 28 July 2003. However, in May 2004, the well was found not producing anymore and could no longer develop steam pressure to initiate steam discharge. It is believed that the production zones may have been blocked during the cementing operations while drilling an adjacent well, 313D. Drilling of well 313D was done from 3 November 2003 to 22 April 2004. A permeable fault intersecting well 307D was encountered while drilling the new well from 1,060 m until a total loss of circulation was encountered at 1,100 m. A series of cement plugs were conducted to seal off the loss zones from 14-17 January 2004. This correlated with the sudden loss of steam flow (11 kg/s) from a steam separator in the area connected to well 307D during the said dates.

The drilling of another well, 419D, in the same field but in the Upper Mahiao sector, began on 31 January 2004. The well was programmed to a total depth of 2,900 m MD/2,663 m VD, but the well encountered drilling interference with a nearby well, 409D, which resulted in its cessation of discharge, while blind drilling in the 12 ¼-in. section of the hole starting from 823 m. The drilling of well 419D was then prematurely terminated at a depth of 1,269 m.

Table 1: Typical well profile of wells in the Leyte Geothermal Production Field (LGPF) in the Pilippines.

	Hole Size			
	26"	17-1/2"	12-1/4"	8-1/2"
Measured depth	0-110 m	110-450 m	450-1500 m	1200-300 m
Casing O.D.	20"	13-3/8"	9-5/8"	7-5/8"
Casing I.D.	19.124"	12.415"	8.681"	6.875"
Casing type	Surface	Anchor	Production	Slotted liner
Approximate temperature	50-150 °C	80-200 °C	110-220 °C	220-350 °C
Static formation bottomhole circulation temperature	60-100 °C	60-110 °C	60-150 °C	80-220 °C
Average drift angle	0-2.5°	0-2.5°	30-45°	30-45°
Likely contaminants	Cement, acid minerals, reactive clays such as smectite, illite, etc.	Cement, oxygen, acid minerals, reactive clays such as smectite, illite, etc. Recycled sump water	Cement, oxygen, acid minerals, reactive clays such as smectite, illite, etc. Recycled sump water, geothermal fluids with chlorides of 5000 to 8000 ppm.	Cement, oxygen, acid minerals, reactive clays such as smectite, illite, etc. Recycled sump water, geothermal fluids with chlorides of 5000 to 8000 ppm.
Remarks	Losses, soft with boulders, above water table. Steam infrequent	Losses, above water table at about 500 m. Induced draft cooling tower on for drilling. Steam infrequent	Losses, above water table at about 500 m. Induced draft cooling tower on for drilling. Steam kicks likely	Losses, above water table at about 500 m. Induced draft cooling tower on for drilling, with returns. Drilling blind with water and occasional mud slugs if recovery is impossible. Steam kicks likely. No cement except at 9-5/8" casing shoe.

Table 2: Location and drilling data for the LGPF wells drilled with aerated fluids.

	Well 422D	Well 315D	Well 421D
Location	Upper Mahiao	South Sambaloran	Upper Mahiao
Pad	406	300B	406
Elevation	571.58 m AMSL	824.69m AMSL	571.58 m AMSL
Wellhead Coordinates	1,236,048.88 m N	1,234,412.00 m N	1,236,055.56 m N
	460,588.42 m E	461,925.00 m E	460,549.70 m E
12-1/4" section			
Date Drilled	Aug 07 to Sep 05, 2005	Oct 15 to Nov 04, 2005	Nov 29 to Dec 31, 2005
Drilling time (h)	145	130	183.5
Depth Drilled (m)	997	752	1025
Depth Range	654-1651 m	906-1705m	682-1707 m
Average Penetration Rate (m/h)	6.90	5.79	5.59
Bits Used	9	9	7
Mud/Water Pumping Range (gpm)	300-810	200-550	300-850
Air Flow Range (scfm)	1000-3200	400-3200	550-3600
Temperature Range (°C)	10-154	18-66	11-204
8-1/2" section			
Date Drilled	Sep 13 to Oct 03, 2005	Nov 13 to Nov 21, 2005	-
Drilling time (h)	189	17	-
Depth Drilled (m)	940	46	-
Depth Range	1650-2590 m	1814-1860m	
Average Penetration Rate (m/h)	5	2.70	-
Bits Used	13	4	-
Mud/Water Pumping Range	200-486	180-550	-
Air Flow Range	1400-3500	2000-3200	-
Temperature Range	10-120	20-41	-

In geothermal drilling in the Philippines, when zones of total lost circulation are encountered, the use of mud is stopped, and blind drilling with water is conducted in order to save on mud and chemical additives. Now that blind drilling with water, which was previously deemed more economical than drilling with aerated fluids, was causing adverse economic consequences through well interference, drilling with aerated fluids was again viewed as a substitute.

The wells that were drilled during the tenure of the PNOC-EDC–Weatherford Aerated Fluids Drilling Project were 422D, 315D and 421D, in this order. Wells 422D and 421D were drilled in Pad 406 of the Upper Mahiao sector, near the affected well 409D, while 315D is located in Pad 300B of the Malitbog-South Sambaloran sector, in the same pad where 313D drilling caused massive interference with other wells.

Rigs 8 and 12 of PNOC-EDC were used for the project. Rig 8, a Continental Emsco D-3 electric rig, was used to drill wells 422D and 421D. Rig 12, which is a Romanian Model TF-25 single-drum mechanical rig, was used to drill well 315D. The drilling depth range of the two rigs is 8,000–12,000 ft. The rigs used a 13 5/8-in. x 3000 psi double ram and a 13 5/8 -in. x 3000 psi annular BOP to meet the anticipated pressure requirement.

The equipment for aerated fluids geothermal drilling consisted of three 1,500 cfm / 200 psig Quincy QSS primary air compressors; two 1,500 psig Joy WB-12 two-stage air pressure boosters; one 1,500 psig meter run; one 2,000 psi Barton dry-flow recorder; one 50-500°F Barton temperature recorder; one 1,500 psig Gardner-Denver single-acting triplex mist pump; two 1,500 psig Texsteam Model 5007 chemical injection pumps; one set of 2,000 psig main air supply line piping; one 2,000 psig floor manifold; one 500 psig Williams Model 9200 geothermal rotating head; one banjo box or flow tee; one 10-in. emergency shut-down (ESD) valve; one 10-in. throttle valve; and one air/fluid/steam separator.

Compared with previous aerated drilling operations conducted in the country, the equipment used in the project differs in the following points:

1. Throttle/choke valve. The use of a throttle valve to control the flow of liquids from the hole effectively exercised a measure of control on the bottomhole pressure. Previous air drilling projects did not use a choke or throttle valve.

2. Greater compression capacity. Three compressors (1,500 cfm / 200 psig) were used in this project, as opposed to previous projects that used two (1,600 cfm / 125 psi); the number and capacity of the boosters used were the same as before.

3. Computerization. The use of downhole well-profiling software and computers to model the system and isolate the operating envelope at which the hole can be drilled underbalanced.

4. String float subs. There is no mention of the use of string float subs in previous drilling operations involving aerated fluids. The use of this device allows for faster connections as pressure within the string no longer needs to be bled off.

AERATED FLUIDS DRILLING OPERATION

Underbalanced drilling, as defined by the International Association of Drilling Contractors, is "drilling with the hydrostatic head of the drilling fluid intentionally designed to be lower than the pressure of the formations being drilled." This can be induced by adding natural gas, nitrogen or air to the liquid phase of the drilling fluid.

Underbalanced drilling techniques are commonly divided into three categories:

1. Performance drilling: the application of air, mist or foam drilling fluid systems to drill subhydrostatically. It aims to reduce drilling costs by increasing the rate of penetration.

2. Managed pressure drilling: drilling with a closed, pressurizable fluid system to more precisely control the wellbore pressure profile. It intends to ascertain the downhole pressure environment limits and to manage the annular hydraulic pressure profile accordingly.

3. Underbalanced reservoir drilling: drilling with the borehole pressure designed and maintained below reservoir pressure to intentionally invite fluid influx. It is intended to increase reservoir productivity by reducing formation damage and enhancing reservoir characterization.

Since the main objective of the project was to determine if the use of aerated drilling fluids can minimize interference with adjacent wells during drilling, the techniques employed by Weatherford for the project were focused on underbalanced reservoir drilling and managed pressure drilling. Also, unlike the previous aerated fluids drilling projects, it was not focused on performance drilling. Operational procedures and decisions were concentrated on intentionally inviting fluid influx into the well being drilled and keeping drilling fluids away from the other wells adjacent to it. In fact, drilling was restricted to periods when circulation was present. Also, when circulation losses were encountered, operational parameters were immediately adjusted to regain circulation as soon as possible prior to drilling ahead. The improvement in the rate of penetration was, therefore, not prioritized. Managed pressure drilling techniques were also used, as information pertinent to drilling parameters was consistently gathered and processed using well-profiling software to periodically model the downhole pressure environment.

It is interesting to note that the previous use of aerated fluids limited it to drilling the 8 ½-in. section of a well. In LGPF, particularly for wells 422D and 315D, aerated fluids were used to drill the 12 ¼-in. and 8 ½-in. sections of the hole, while with well 421D, drilling with air was limited to the 12 ¼-in. section of the hole. This marks the first time that aerated fluids drilling technology was utilized to drill the 12 ¼-in. section of a geothermal well in the country. This was done in consideration of the fact that interference with other wells was previously encountered while drilling in these depths. The upper sections of the well, the 26-in. and 17 ½-in. sections, were drilled using conventional drilling methods.

As to the type of fluids used during drilling, aerated mud was first used to drill the upper sections of the wells. A shift was later made to aerated water when drilling reached the deeper sections of the wells. A similar technique was previously used for drilling well Palinpinon-18D. In this well, aerated mud was used while drilling from 5,050 ft to 9,175 ft, and aerated water was utilized from 9,175 ft to 10,730 ft.

A corrosion control program was implemented to minimize the degradation of drilling materials and equipment as a consequence of the use of aerated fluids. It involved the treatment of the drilling fluid used and the injection of corrosion inhibition chemicals into the system. The target corrosion rate of the program, as indicated by corrosion ring coupons placed in the cross-over heavyweight drillpipe and in the kelly saver sub, was < 2 lb/sq ft/year.

WELL INTERFERENCE MONITORING

PNOC-EDC instituted a well interference monitoring program for each of the three wells drilled using aerated fluids in order to determine whether the use of aerated drilling has minimized, if not eliminated, interference within the shallow to intermediate depths of the reservoir. The objective was to monitor for breakthroughs of drilling fluids/materials that may be detrimental to production wells surrounding the well being drilled.

The parameters that were monitored on the surrounding production wells were: (1) total suspended solids (TSS) and color of samples, (2) wellhead pressure (WHP) and (3) steamflow of the separator vessels where the wells were hooked up. The collection of samples was started at twice a week during re-entry of the hole being drilled. Once a partial loss of circulation (PLC) or total loss of circulation (TLC) was experienced, sample collection was increased to once a day. The amount of TSS found will be indicative of the level of interference being experienced in adjacent wells to the hole being drilled.

RESULTS

Well 422D, with an elevation of 571.78 m above mean sea level (AMSL) and located in pad 406 in Upper Mahiao, was the first of three wells drilled using aerated drilling fluids technology in LGPF. Drilling using aerated fluids for this well started at the 12 ¼-in. section until the target depth of the 8 ½-in. section. The operation was completed within 65 days. Total actual aerated drilling time was 32 days.

Most of the 12 ¼-in. section was drilled with full returns, except for an incident involving a TLC and where pipe got stuck, left a fish-in-the-hole and required a sidetrack. Drilling for this section covered a depth range of 654 m to 1,651 m, or 997 m, and required nine bits. Average penetration rate was 6.90 m/hr. It should be noted that this figure, along with other data in this section involving penetration rate, is inclusive of periods of drilling conducted not using aerated drilling. The rate of mud/water pumping was from 300 to 810 gpm, and air flow from 1000-3200 scfm, with the temperature ranging from 10-154 °C.

The 8 ½-in. section was drilled with full returns to target depth. All of the planned target geological structures of this well were encountered. However, the planned depth of 2,700 m was not reached because PNOC-EDC decided to TD the well when tight hole and a suspected collapsing formation was encountered at 2,590 m. Drilling for this section covered a depth range of 1,650-2,590 m, or 940 m. Thirteen bits were used on this section, two of which were worn out immediately as the drill string casing protectors were falling off, thus wearing the bit severely. The average penetration rate was 5 m/hr. The rate of mud/water pumping was from 200 to 486 gpm, and air flow from 1400 to 3,500 scfm. Temperature had a minimum of 10°C and a maximum of 120°C.

One of the lessons learned after drilling well 422D involved the fact that circulation must be maintained during drilling to minimize the chances of having the pipe getting stuck. If circulation losses are encountered, full circulation should be regained before drilling ahead. This can be accomplished by promptly adjusting the air and water injection parameters with respect to the behavior of the well. While drilling the 8 ½-in. section, circulation was regained by starting with a low mud/water pumping rate (300 gpm) and a high air flow rate (3,300 scfm) and subsequently increasing the water-pumping rate once circulation was established to keep the bit cool.

It was also realized that, based on the formation pressure profile and the software-calculated circulating pressure, 422D was drilled mostly at a slightly overbalanced state. When drilling underbalanced in well 422D, problems with high-temperature returns and well kicks were encountered. Drilling slightly overbalanced minimized this problem. Lastly, the BOP stack must be aligned with the crown block before aerated fluid drilling starts in order to maximize the life of the stripper rubbers. A total of 12 stripper rubbers were worn out during the course of drilling this well because of this misalignment.

WELL 315D

Well 315D, with an elevation of 824.69 m AMSL and located in Pad 300B of South Sambaloran, was the second well. Aerated fluids drilling was utilized for drilling the entire 12 ¼-in. section, but plans to drill the entire 8 ½-in. section of 315D with aerated fluid were canceled, and drilling continued using blind drilling. However, aerated fluids were briefly utilized to drill the 8 ½-in. section when the drill string got stuck while blind drilling. Weatherford was released when a major loss zone was encountered. The aerated fluid drilling operation was completed within 51 days. Total actual aerated drilling time was 28 days.

The entire 12 ¼-in. section was drilled with full returns, and the planned target depth of the 12 ¼-in. section of this well was attained. PNOC-EDC experimented with drilling ahead blind in this section and was able to drill from 1,530 m to 1,577 m. However, cuttings were observed in a nearby production well, so blind drilling was immediately stopped. A depth range of 906-1,705m, or 752 m, was covered for this section, requiring nine bits. Average penetration rate is 5.79 m/hr. Mud/water pumping ranged from 200 to 550 gpm, and air flow from 400 to 3200 scfm. Compared with the other two wells drilled using aerated fluids in the area, 315D was cold, with a temperature range of only 18-66°C.

Aerated fluid drilling was used to assist in drilling through a portion of the 8 ½-in. section from 1,814 m until a massive loss zone was encountered at 1,860 m. While drilling this section of the hole, a jet sub was installed at 650 m from the surface to improve the lifting of cuttings. Weatherford was released when a major loss zone was encountered at 1,860 m. The drilling of this section registered a penetration rate of 2.70 m/hr and required four bits. Mud/water pumping ranged from 180 to 550 gpm, and air flow from 2,000-3,200 scfm. The temperature range at this section was lower, pegged at 20-41°C.

Drilling well 315D revealed that drilling wells with low formation pressure at high elevation would require additional compression capacity. At an elevation of 824 m AMSL, the maximum output of the air compression package was only 3,200 scfm. However, software computations revealed that more than 3,200 scfm of air was needed to drill the deeper portion of the 12 ¼-in. section of well 315D using the minimum required vertical velocity to transport cuttings (150 ft/min). Increasing the water rate to increase velocity would result in loss of circulation due to low formation pressure. Using 3,200 scfm and the maximum water rate (before circulation loss occurs) was not enough to lift the cuttings.

This deficiency was compensated by using high-viscosity mud sweeps everytime half of the length of the kelly has been drilled. However this method involved additional drilling time since circulation is momentarily lost when circulating out the sweep, and drilling must stop until the sweep arrives at the surface. The addition of a fourth compressor should be considered when aerated fluids drilling is again utilized in a well with similar wellhead elevation and formation pressure. The same can be said for the 8 ½-in. section, where more than 3,200 scfm of air was required, together with a sufficient water pumping rate, to lift the cuttings to the surface.

WELL 421D

Well 421D, which is located near well 422D, was the last of the three wells. For this well, aerated fluids drilling was confined to the 12 ¼-in. section. Aerated fluid drilling operation was completed after 39 days. The entire 12 ¼-in. section was drilled with full returns.

All of the planned target geological structures in the 12 ¼-in. section of the hole, including a number of unexpected drilling breaks, were encountered. These geological structures brought about momentary partial, and sometimes total, loss of circulation, but circulation was immediately restored after adjustments were made to aerated drilling parameters. Drilling this section covered the depth range of 682-1,707 m or a depth drilled of 1,025 m at a rate of 5.59 m/hr and requiring seven bits. Mud or water pumping rate ranged from 300-850 gpm, while air flow fluctuated in between the broad range of 550-3,600 scfm. The temperature of this well was high, the highest of the three wells drilled with air, with its range pegged at 11-204 °C.

With the elevated temperature levels of well 421D, the following lessons were learned on how to drill using aerated fluids in geothermal wells like it.

First, that the use of controlled overbalanced drilling during appropriate conditions, aside from underbalanced drilling, can be utilized to keep rapid temperature spikes and well kicks at bay, especially in multi-feed zones, thereby allowing drilling operations to proceed continuously. Restricting drilling to periods when circulation was present also helped to ensure that drilling problems were minimized. However, problems were brought about by the constant fluctuation in the performance of the rig mud pumps, causing the constant re-adjustment of other aerated drilling parameters and making it difficult to accurately tune them to bring about underbalanced, balanced or overbalanced conditions.

When drilling wells in areas with proven high steam output, it is necessary to have accurate and dependable parameter values, especially on mud/water pumping rates, as it exercises a vital role in the balancing act between maintaining circulation and controlling temperature. Also, the use of cold fresh water, instead of fluids coming from the active tanks, for a calibrated period of time, is useful in staving off sharp increases in temperature.

Finally, it is more time-efficient, especially in areas where temperature is at an elevated level, to address temperature concerns by lowering the air flow rate after making a connection, in order to accelerate the process of regaining circulation, and by immediately increasing mud/water pumping values during circulation for returns after kelly down, and, at times, quenching the well before connection.

A number of other benefits for geothermal drilling were also realized by the use of aerated fluids to conduct underbalanced drilling. They include: (1) absence of differential pressure pipe sticking, (2) the availability of geological information from the steady supply of cuttings brought about by constant circulation, and (3) good hole cleaning.

WELL INTERFERENCE MONITORING

The results of the well interference monitoring program of each of the three wells drilled using aerated fluids, as provided by PNOC-EDC, are presented in this section. The graphs reflecting the level of TSS detected in wells adjacent to wells 422D, 315D and 421D are presented in Figures 1, 2 and 3.

Wells 406, 412D, 413D and 416D were the wells that were monitored for TSS values when well 422D was drilled (Figure 1). During the drilling of the 12 ¼-in. section of well 422D, which spans the depth of 654-1,651 m, spikes in the TSS values generally occurred when TLCs were encountered (more particularly TLCs No. 3 to 8) or when cementing activities were conducted. It should be noted that the increase in the TSS values were temporary since cementing activities were immediately concluded and, more importantly, circulation losses were addressed through the use of aerated fluids. This is because with aerated fluids drilling, good circulation is still possible even at the loss zones, as opposed to drilling without returns or blind drilling. TSS values went back to normal after cementing and after circulation was restored.

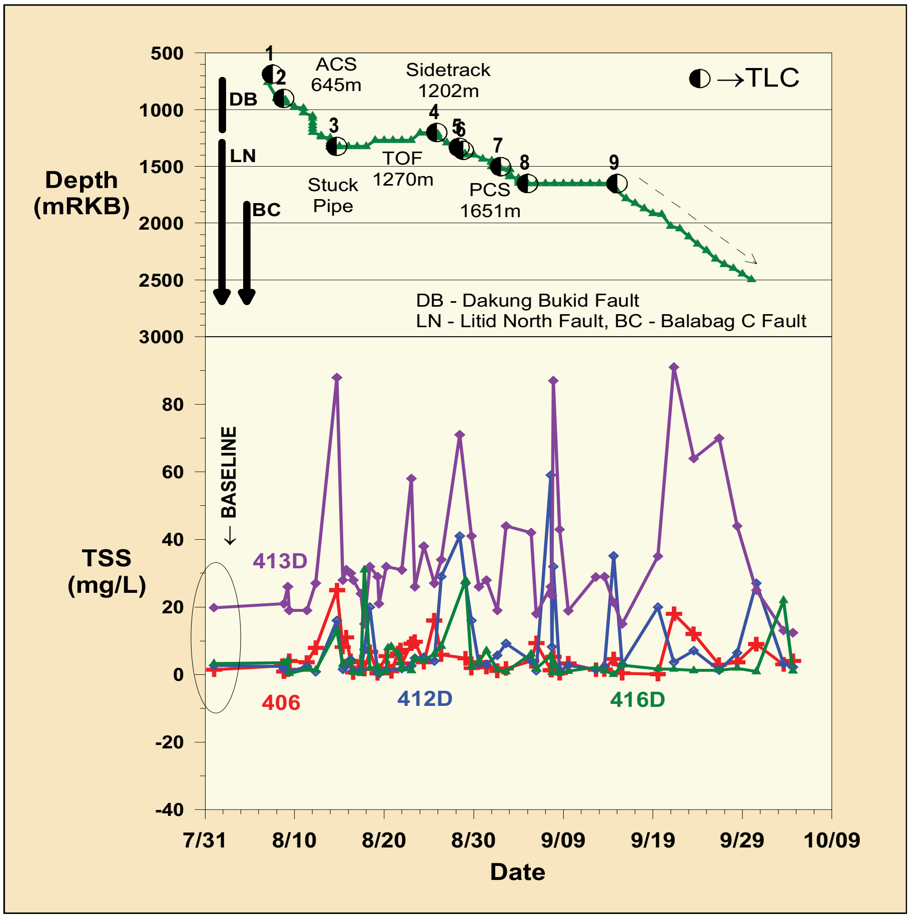

Figure 1: During the drilling of the 12 ¼-in. section of well 422D, spikes in the TSS values were monitored in wells 406, 412D, 413D and 416D. The spikes generally occurred in total losses of circulation or during cementing activities.

It should also be noted that the control and minimization of well interference is very important in the 12 ¼-in. section of the hole, since this is the area where massive well interference was previously encountered when drilling well 419D. As a precautionary measure,

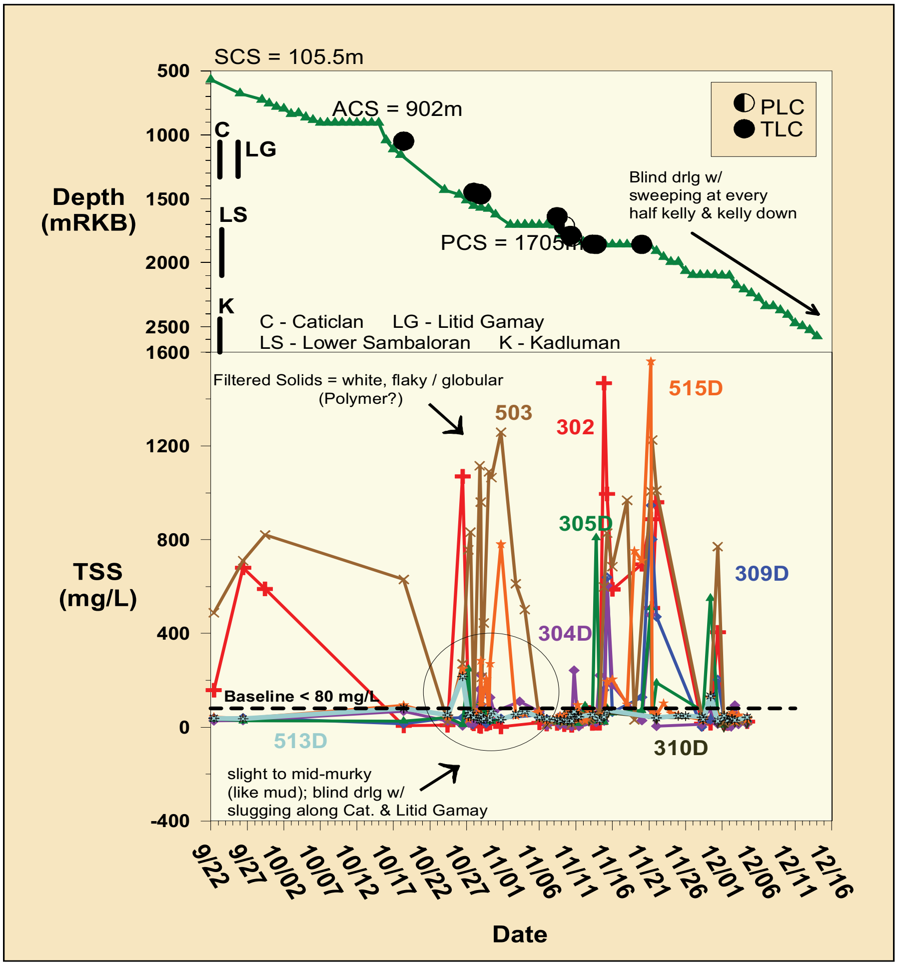

Figure 2: Since both the 12 ¼-in. and 8 ½-in. sections of well 315D utilized both aerated fluids drilling and blind drilling, this graph is most reflective of the effects that these two different drilling techniques have on the levels of TSS in the wells adjacent to the well being drilled. It shows that while drilling with air, TSS levels in wells 513D, 503, 515D, 302, 304D, 305D, 309D and 310D rose rapidly when there was total loss of circulation but soon returned to their baseline values. When the well was drilled blind, and in the absence of circulation losses, the TSS values of adjacent wells spiked and continued to increase.

PNOC-EDC has increased the space or radius between wells to more than the previous value of 200 m. Also, when cementing is performed during drilling operations, certain production wells are shut momentarily to avoid damage. The spikes observed during the drilling of the 8 ½-in. hole using aerated foam that do not coincide with either cementing or loss of circulation are said to have been caused by fine cuttings that were transported during circulation losses. No permanent damage was found in any of the wells that were monitored after the drilling of well 422D.

When well 315D was drilled, the production wells monitored for interference were 513D, 503, 515D, 302, 304D, 305D, 309D and 310D, the results of which are shown in Figure 2. Since both the 12 ¼-in. and 8 ½-in. sections of well 315D alternately utilized both aerated fluids drilling and blind drilling, this graph is most reflective of the effects that these two different drilling techniques have on the levels of TSS in the wells adjacent to the well being drilled. It shows that while drilling well 315D with air, TSS levels rose rapidly when there was total loss of circulation, more particularly during 26-28 October 2005, but soon returned to their baseline values.

However, when the well was drilled blind from 29-31 October 2005, and in the absence of circulation losses, the TSS values of adjacent wells spiked and continued to increase, particularly for wells 503 and 515D. In fact, interference with well 304D was evident when PNOC-EDC decided to drill blind with water from 1,530 m to 1,577 m. Blind drilling was stopped when this occurred. For the 8 ½-in. section of the hole, Weatherford was only able to drill with air in this section on 13-14 November 2005, after which blind drilling was again employed. During the period that air drilling was used, only well 305D was affected, and this was because there was total loss of circulation during drilling.

After 14 November, the effect of blind drilling on TSS levels was immediately felt, as values reached their highest levels and all of the wells were immediately and constantly affected by interference from the well being drilled. The results of the well interference monitoring program therefore provide tangible evidence of the importance of utilizing aerated fluids drilling, as compared with and instead of blind drilling, in order to minimize well interference when drilling wells infill.

The results of the monitoring done for well 421D are shown in Figure 3. Six wells were monitored when drilling was undertaken for well 421D. These are wells 406 and 416D in Pad 406, wells 409 and 411D in Pad 409, and wells 412D and 414D in Pad 401. The results show that during the course of aerated drilling in the shallow to intermediate section of the reservoir, interference with the other wells has been minimal, restricted only to periods when there was either cement plugging (CP) or partial/total loss of circulation (P/TLC). At times when there were TLCs or PLCs, however, the interference that took place was at best temporary and momentary, as the subsequent results of the monitoring show that the amount of TSS in the affected wells immediately went down and returned to baseline levels.

Besides, of the six wells being monitored, only three wells were affected, particularly wells 409, 411D, 416D, and only for very short periods of time. It should be pointed out that four of the six spikes seen in the graph, those before 15 December, occurred during cement plugging.

Furthermore, the fact that a major part of the 12 ¼-in. section of 421D was drilled at a state of "controlled overbalance" at times does not reflect or appear in the graph, providing evidence that the practice of this technique does not interfere with adjacent wells. It also supports the contention that the well does not have to be underbalanced at all times to accomplish the minimization of well interference during infill drilling.

The use of "controlled overbalanced

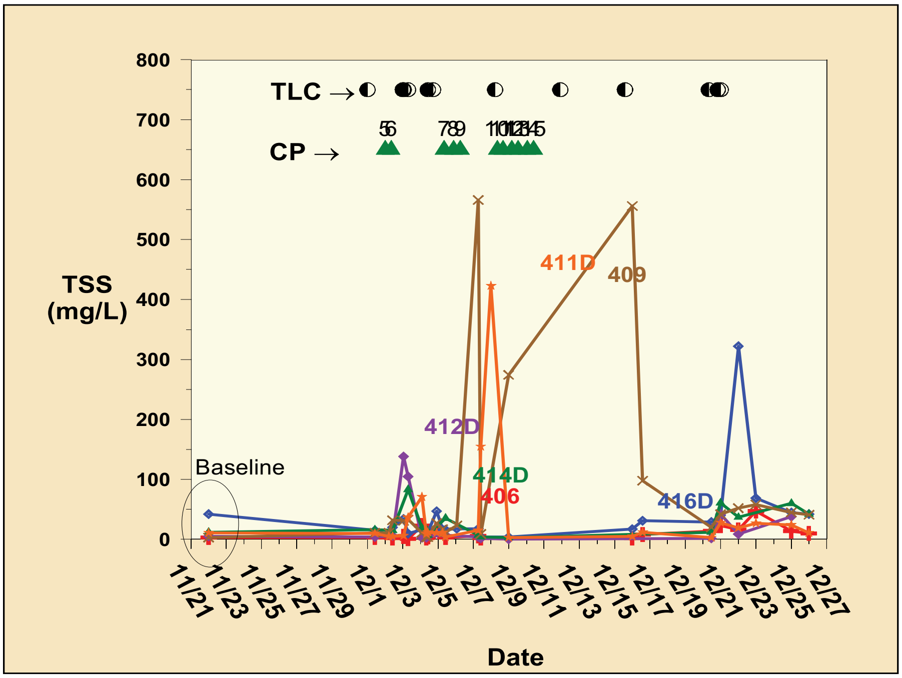

Figure 3: Monitoring for well 421D shows that during the course of aerated drilling in the shallow to intermediate section of the reservoir, interference with the other wells was minimal, restricted only to periods when there was either cement plugging or partial/total loss of circulation.

drilling," aside from underbalanced drilling, in appropriate conditions can contribute greatly in gaining control over the temperature fluctuation of the well during the course of drilling, especially in multi-feed zones, and especially with high-temperature or "hot" wells.

In relation to the results of the well interference monitoring program, it should be emphasized that during and after the drilling of three wells in LGPF using aerated drilling fluids, no production well in the Leyte Geothermal Production Field has "ceased to discharge" or "died" as a consequence of aerated fluids drilling activities performed in areas adjacent to these wells.

CONCLUSION

Aerated fluids drilling, though not new in the Philippines, was recently employed to determine if well interference can be minimized, if not eliminated, while drilling within shallow to intermediate depth of an actively producing two-phase zone of a reservoir, more particularly a reservoir in the Leyte Geothermal Production Field, Philippines. Infill drilling activities of PNOC-EDC, the company managing the geothermal field, which utilized blind drilling and cement plugging of loss zones, have lately been adversely affecting production wells in the neighborhood of the well being drilled.

Using aerated fluids drilling technology, three new wells were drilled infill at LGPF to assess whether the technology can be employed as a solution to the problem of well interference during infill drilling. An approach that combined underbalanced reservoir drilling and managed pressure drilling techniques was used for the project, with adjustments and corrections made to the procedures employed as circumstances required. The results achieved with the drilling of wells 422D, 315D and 421D in LGPF, especially that from the well interference monitoring program conducted by PNOC-EDC, reveal that aerated fluids drilling technology, by establishing good circulation during drilling even at loss zones, is capable of minimizing well interference during infill drilling.

Compared with the previous practice of using blind drilling and cement plugging of loss zones, and even discounting the other benefits that can be derived from drilling underbalanced, aerated fluids drilling has the undeniable advantage of successfully allowing the drilling of new infill wells in the geothermal field without adversely affecting actively producing ones.

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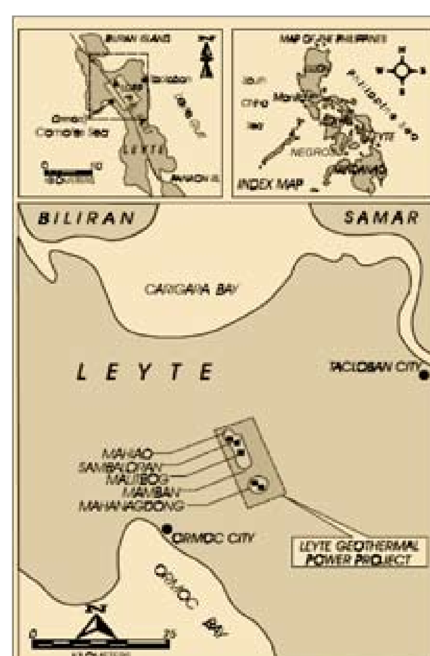
15. *PNOC-EDC. "Well Monitoring Program for Well 421D."*

This article is based on a presentation made at the 2006 SPE/IADC Managed Pressure Drilling and Underbalanced Operations Conference & Exhibition, 28-29 March 2006, Galveston, Texas.



PNOC-EDC

This map shows the location of the Leyte Geothermal Production Field.