Proceedings World Geothermal Congress 2010
Bali, Indonesia, 25-29 April 2010

Bulalo 99 Workover: Complex Zonal Isolation

Angelito C. Torres and Wilhelmino Q. Lim

14F 6750 Building, Ayala Avenue, Makati City, Philippines 1226

angelito.torres@chevron.com, Wilhelmino.Lim@chevron.com

Keywords: peripheral fluids, zonal isolation, marginal recharge, downflow, annulus casing packer

ABSTRACT

A major problem encountered by mature geothermal fields is the influx of cooler peripheral fluids into the production area. This tends to reduce the productivity of the field by curtailing steam flash. After 30 years of commercial operation, some wells in the Mak-Ban Geothermal Field, Philippines are affected by cooler edge fluids which invade the two-phase region of the reservoir. Cooler fluids tend to short-circuit deep into the reservoir through wellbores of affected wells and eventually invade the production zones of nearby wells. This causes their steam production to drop and leaves their signature in terms of chloride dilution and increasing non-condensable gases in case of steam wells. With this damaging reservoir problem, there is a need to isolate and cement the unwanted zone. A workover employing zonal isolation addresses this problem.

The complexity of this workover is further enhanced when the unwanted cool zone lies between two productive zones. In order to solve the problem, the existing perforated liner was cut below the cool zone and retrieved. A high temperature annulus casing packer was run together with stage cementing tool and blank liner to isolate the cool zone. The top of this blank liner was in uncased open hole. The blank liner was set to ensure that the productive zones, above and below the cool zone, will not be blocked. The blank liner was cemented across the cool zone followed by running perforated liner from top of cemented blank liner up to casing shoe. The cement inside the blank liner and the float was cleaned out to open the lower production zone. This provided access to the upper and lower steam zones while isolating the cool zone. Subsequent tests have shown the cool zone isolation to be mechanically successful.

This paper details the original planned operation, the obstacles and difficulties encountered while executing the plan, the steps taken to reach a successful completion and the lessons learned to enhance future execution of similar work.

1. INTRODUCTION

Influx of cooler peripheral fluids into the production area is a major problem encountered by mature geothermal fields. In Bulalo, a well manifested a downflow of cooler fluid from the shallow two-phase zone into the deeper brine zone. The influx of cooler peripheral fluids through the wellbore had affected the productivity of geothermal wells.

In the case of Bul-99, a sudden drop in its productivity (especially brine rate) accompanied by decrease in chloride and increase in NCG, led to the suspicion that dilute cooler fluid could be downflowing into the wellbore. This suspicion was confirmed when a Pressure Temperature and Spinner (PTS) survey was conducted and found that, indeed, cooler fluid was entering the wellbore at 3733' md and downflowing through the wellbore while the well was still flowing.

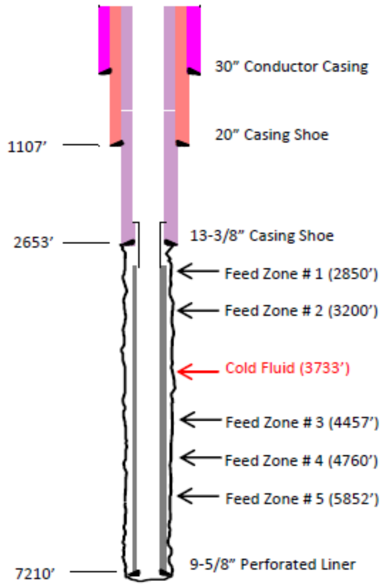

Figure 1: Bulalo 99 Wellbore Schematic

In order to solve the problem of cold fluid influx, a workover program employing zonal isolation will be conducted. This will be done using high temperature annulus casing packer together with stage cementing tool run with blank liner and cement across the cold zone. The cemented liner will block the downflow of cooler fluids which invade the lower production zones.

2. BULALO 99 WELL CONDITION

The productivity of Bulalo-99 had been very stable from the time it was flowed in 1996 through late 2003 when its brine rate started to increase from 300 kph until it peaked to 500 kph in 2005. It eventually dropped back to 100 kph in 2006. That event was accompanied by remarkable decline in its chloride content which suggests contamination by cooler, more dilute fluids. Historically, Bul-99 was producing fluid contaminated by 17% marginal recharge fluid (MR) but in February 2005, the contamination was doubled to 34%. Coincidentally, there was a significant increase in its NCG, particularly CO_2 together with drop in its H_2S which signify steam condensation. The drop in its brine rate from 500 kph down to 100 kph in 2006 was, likewise, accompanied by a drop in its steam rate from 270 kph in December 2005 to 180 kph in 2007. The "invasion" by cooler, more dilute fluid was confirmed by a PTS (Pressure Temperature Spinner) survey conducted in April 2008 (Figure 2). It was shown that cold dilute fluid entered the wellbore at 3733' MD, downflowed and exited at 6959' MD. The downflow effectively killed all the zones below the liquid entry and reduced the well's steam rate by 90 kph.

Overlying the MR entry depth are two steam zones unaffected by dilution. That is where the well currently derives its productivity. Bulalo-99 is currently producing 180 kph steam.

3. ZONAL ISOLATION METHODOLOGY

A workover rig with sufficient capacity was needed to conduct the zonal isolation procedure. In order to isolate the unwanted zone the existing perforated liner was cut below the influx zone and replaced with a blank liner cemented in place. The overlying steam zones are productive and they need to be preserved. Therefore the top of cemented blank liner should not extend above them. A pre-perforated liner will be run from the top of cemented liner up to casing shoe after the liner is cemented in place

3.1 Cut and Pull

Casing and liner were to be cleaned out,, casing cutter run and the existing perforated liner cut at the desired depth. Next run a casing spear and engage casing through top of liner adapter. Attempt to pull casing. Pull casing spear if unable to pull cut liner. Reset casing cutter and cut midway of liner to be retrieved. Repeat the procedure until everything down to desired depth retrieved.

Cut and pull operation can be done in single run by spacing space out the casing cutter and casing spear a little more than the length of liner to be retrieved.

3.2 Open-hole Caliper Survey

The purpose of caliper survey is to determine the approximate open hole size in preparation for liner cement job. The annular volume must be determined as accurately as possible in order to ensure that the upper steam zones will protected from cement. Pumping too much cement during liner cementing could damage the fractures of steam zone.

Another benefit of running open-hole caliper survey is to select the best location for inflating the annulus casing packer (ACP). The packer should be inflated in competent and gauged formation for effective isolation. Setting packer in loose or washed out section has higher risk of unsuccessful cementing job.

3.3 Setting and Cementing Annulus Casing Packer

Select location and set annulus casing packer based on the result of caliper survey. Make-up annulus casing packer assembly (Figure 3) in the following order: Over Shot Shoe, Baffle Collar (with rigid centralizer), Annulus Casing Packer (ACP), ACP Handling Pup, Hydraulic Stage Cementing Tool, Required Blank Liner, Liner Setting Sleeve, Polished Bore Receptacle (PBR).

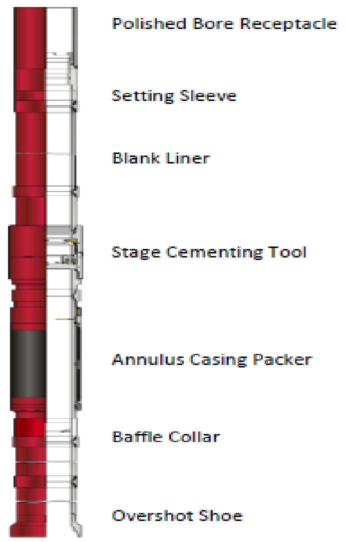

Figure 3: Annulus Casing Packer Assembly

Make-up the Polished Bore Receptacle with the plug set (wiper plug and closing plug), Liner Setting Tool, and drill pipe required to surface (Figure 4). Circulate hole with pressure not exceeding ACP inflating pressure. Run and sit on top of liner stump, slack-off complete liner weight. Circulate hole, drop bottom dart for first shut-off plug and pump inflation cement slurry. Displace cement with pre-flush followed by fresh water. Increase pressure to shear the shut-off plug pin.

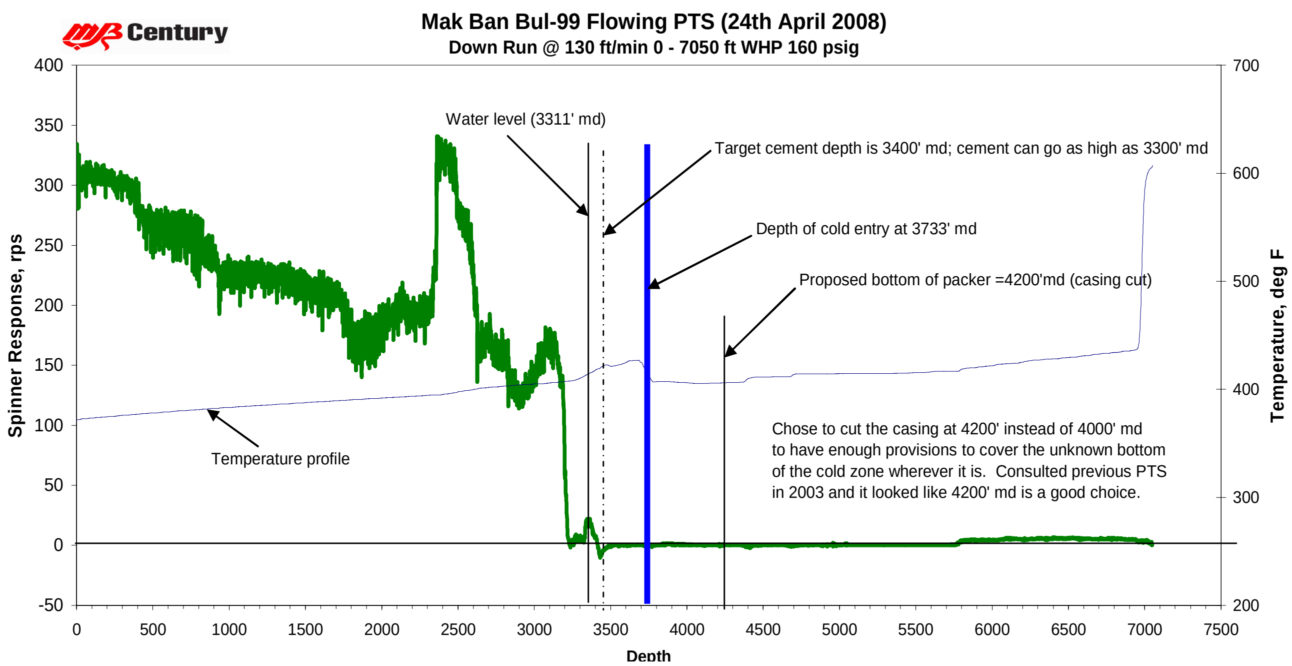

Figure 2: Bulalo 99 PTS Graph (April 2008)

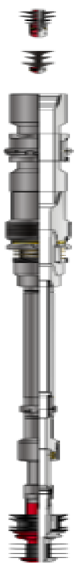

Figure 4: ACP Setting Tool and Plug Set Assembly

Continue displacing cement until wiper plug sits on baffle collar. Increase surface pressure to inflate ACP. After setting ACP, bleed off pressure to zero and check displacement tank to calculate net inflation volume. Take note that in this kind of isolation the section from 13-3/8” casing shoe down to top of PBR is open-hole. Running any assembly on this section should take extra care.

Apply pressure to casing until the ports in the cementing stage tool opens up. Establish circulation to condition hole then mix and pump cement for the annulus. Release top dart and displace with water to engage in the closing plug. Increase pressure to release closing plug and pump the calculated amount of displacement fluid to sit closing plug in cementing stage tool. Check to determine whether cementing stage tool has closed by releasing pressure and observing the volume of fluid bleed-back.

Release the liner setting tool. Circulate on top of PBR to clean-out possible excess cement. Pull out of hole with the liner setting tool.

3.4 Cement Clean-out

Run in hole with 12-1/4” clean-out assembly to clean-out cement debris down to top of PBR. Next run a 9-7/8” bit and clean-out cement inside PBR . This will ensure that the tieback stem will sting-in through the PBR smoothly.

3.5 Running 9-5/8” Perforated Liner

Run 9-5/8” perforated liner inside PBR with liner adapter on top and fabricated tieback stem on bottom. It is necessary to pump water in the annulus to keep the well from flowing. Be ready with a well control string that can be attached on top of perforated liner in the event of well kick. Release the running tool and pull out of hole to surface.

3.6 Casing Clean-out

Make-up and run in hole with 8-1/2” clean-out assembly to drill closing plug, cement and baffle collar. Clean-out and chase debris to total depth. Clean-out fill as necessary depending on the depth of deepest production zone.

4. ACTUAL OPERATION

Bulalo 99 zonal isolation was not conducted as planned due to various troubles encountered during the operation. This was the first time it was conducted in this geothermal field. Although this kind of operation was a pilot run, the contingencies were properly identified during risk assessment and back-up plans were in place.

4.1 Cut and Pull

Made-up and ran in hole 9-5/8” casing cutter to 4200’. Cut the 9-5/8” liner. Made-up and ran in hole 8-1/2” casing spear. Engaged casing spear on top of 9-5/8” perforated liner at 2386’. Gradually pulled out cut liner.

Rig-up 9-5/8” casing tong for breaking-out perforated liner connection. Some joints could not be broken out even using rig tong and the contingency was to use cutting torch to cut the casing. A total of 47 joints were retrieved.

4.2 Open-hole Caliper Survey

The open-hole X-Y caliper survey tool was run down to 4195’. The tool stuck at 3155’ while doing repeat section. Possibly the tool stuck due to differential sticking caused by pumping in the annulus to keep the well dead. The tool was cycled several times in an attempt to free. Tool came free but stuck again at 1600’. The wireline parted after applying maximum pull. Retrieval of the X-Y caliper tool was attempted using different fishing tools without success. A series of obstructions were encountered (wellbore ledges) throughout the open-hole while fishing. Decided to run 12-1/4” convex mill to clean-out wellbore ledges then milled the suspected caliper tool at 4197’ to 4201’. This fishing operation resulted in more than three days of downtime.

4.3 Setting Annulus Casing Packer

The annulus casing packer was prepared, tested, and made up with a 9-5/8” blank liner that took it back to 3400’ md (top of PBR). Ran the assembly and swallowed the 9-5/8” perforated liner stump at 4201’.

Mixed and pumped inflation cement slurry and displaced with water. ACP was inflated at 1450 psi surface pressure. Pressure indicated that the ACP inflated successfully. Increased pressure to open stage cementing tool, stage tool did not open with maximum applied surface pressure of 5600 psi.

The contingency plan, if the stage cementing tool did not open was to run a perforating gun, perforate the casing, set a cement retainer and cement the blank liner. However, it would be safer if the open hole above the blank liner was cased-off first to avoid working in an open hole section. The wellbore might suck the perforating gun while passing through the open hole section where water being pumped into the annulus was going out. Continuous pumping into the annulus is required to keep the well dead.

4.4 Running 9-5/8” Perforated Liner

Prepared the 9-5/8” perforated liner with fabricated stab-in shoe (with lip guide) on bottom and liner adapter on top. The stab-in shoe was cut with lip guide in order the pass the obstruction at 2415’ (inside 13-3/8” casing). Ran in hole 9-5/8” perforated liner and were able to pass the obstruction. It was noticed that every collar was hanging up (possible parted casing) while passing through the obstruction. The 9-5/8” perforated liner (stab-in shoe) was successfully landed on top of PBR setting sleeve at 3423’.

4.5 Cement Clean-out and Milling

An 8-1/2” clean-out assembly was run and cleaned out cement from 3890’ down to 4137’ (stage cementing tool). While pulling out of hole, the clean-out assembly stuck at

3423’ (PBR setting sleeve). Worked and jarred to free pipe for seven hours. Pipe freed and pulled out of hole.

A 8-1/2” milling assembly was run in the well. Milled obstruction at 3423’, reamed up and down several times to ensure obstruction is cleared. Continue running in hole to confirm the clear depth for casing perforation.

4.6 Cementing 9-5/8” Blank Liner

A 4-foot perforating gun with 12 spf was run and fired at 4128’. It was observed that all 12 shots fired.

Ran in hole with 9-5/8” cement retainer together with cementing stinger and set at 4070’. Established circulation and pumped 5 bbls pre-flush. Mixed and pumped 78 bbls cement slurry and observed that pressure was increasing above normal. Continue pumping cement slurry with total of 91 bbls. Pumping had to cease after reaching 5000 psi surface pressure. The pressure increase was attributed to perforation blockage or flash setting of cement. Theoretically 40 bbls of cement slurry went into the annulus.

Made-up and ran in hole 8-1/2” bit to check the top of cement. The top of cement was tagged at 3490’ (bottom of PBR). It meant that no cement was on top of PBR. Drill pipe with a plug catcher was run in the well. Mixed and pumped 29 bbls cement slurry. Redressed the plug catcher and reran in hole to tag top of cement. The top of cement was tagged at 3376’ (33’ above top of PBR).

4.7 Cement Clean-out

Made-up and ran in hole 8-1/2” cement clean-out assembly. Drilled-out cement from 3376’ to 4009’. High torque was encountered from 4009’ to 4037’. The bit was pulled and new bit run in the well down to 7077’. The circulating string then plugged with plastic coating of drill pipe so clean-out operations ceased. This completes the zonal isolation of the cold zone at 3733’.

5. LESSONS LEARNED

During the actual operation of Bulalo 99 Zonal Isolation, there were lessons captured that need to be considered to enhance future execution of similar operations. These lessons learned will help develop better contingency plan with less downtime.

5.1 Bit Clogging

There were two incidents of bit clogging during the entire workover operation for Bulalo 99. The first one was during clean-out run and the other was during the end of operation while cleaning out to total depth. These incidents of bit clogging were associated with the drill pipe inner wall plastic coating. There are high temperature steam zones that may affect the plastic coating causing the plastic to melt or crack.

People should be aware that the new drill pipe available today may be internally coated with plastics to address premature corrosion during storing and shipping. There is a need to check the quality of plastic coating used.

5.2 Lost in Hole Caliper Tool

Conducting of caliper survey before running ACP is important in locating the best section for ACP inflation and having approximate cement volume requirements. Cement volume calculation is important in calculating excess volume of slurry that can be pumped without having the risk of blocking the steam zones above cold fluid influx. However, running a short tool in open hole is risky and the benefit needs to be carefully evaluated.

Instead of running caliper survey, penetration rate during drilling, geologic formation, and spinner response during PTS survey can be used. Minor wellbore washed-out is not much issue since the ACP can inflates up to 3.5 times of its run-in diameter.

Excess cement can be calculated based on ideal hole diameter from top of PBR up to the nearest feed zone. Circulating after cementing below the feedzone to dilute the cement will ensure upper feedzone is not damaged.

Another lesson is making sure that there is available fishing equipment for allwireline tools are run in the hole.

5.3 Unsuccessful Cementing Through Perforation

There were two significant parameters missed prior to cement job through the perforation. The first parameter was the establishment of injection rate through the perforation. This parameter would give an idea of how many perforations are open and the acceptance rate of the wellbore. Another parameter that was unknown was the percent stand-off of the casing in the wellbore and any restrictions that could prevent the slurry from being pumped up the annulus.

Another important parameter missed to consider after establishing injection rate is circulating to cool down wellbore. Circulating will also determine if there is bridge in the annulus that may restrict the flow of cement. It is also important to cool down the well before cementing in order to avoid flash setting of cement.

5.4 Stage Cementing Tool Failed

Although it is hard to determine exactly what caused this incident, there are two scenarios which could explain why the tool did not work successfully. The first scenario is that, the tool did not open due to mechanical problem which made pumping cement impossible. There is no way to test the stage tool from surface just to confirm that the tool is free from mechanical failure.

The second scenario is that the stage tool did open however there was a bridged section in the annulus that restricts the flow of slurry. Due to low rate of pumping, the cement slurry might have flash set across the bridge in the annulus which made the pumping pressure shoot up to 5600 psi. This scenario can be further verified by the incident that took place after the casing was perforated above the stage tool to complete the cement job. While pumping cement through the perforation, the pressure again went up to 5000 psi and the cement job was aborted.

The success rate of cementing stage tool in geothermal application using cement as inflation fluid should be reviewed carefully. Using water as inflation fluid is safer but cannot be used in geothermal due to high wellbore temperature. Water will expand once exposed to high temperature which may burst the ACP rubber or collapse the casing.

On the other hand, although cement contains a lot of water in the mixture, the inflation slurry was designed at zero free water and below 150cc fluid loss. The slurry will set faster as the temperature increases therefore not allowing the water to separate from the cement mixture which may create pressure.

An alternative to stage cementing tools such as perforating and using a cement retainer should be considered.

5.5 Obstruction at 3423' (Stab-in Shoe)

The clean-out BHA stuck at 3423' while pulling out of hole. This was the depth of the PBR setting sleeve. The setting sleeve has smaller diameter where the stab-in shoe is resting. The sleeve and even the stab-in shoe might have been deformed by bit impact creating the obstruction. Also the stab-in shoe profile had sharp edge which may not have been sufficient to stand the total liner weight causing the lip of casing to protrude inward.

This incident can be avoided considering the use of stop collar. The stop collar will be placed above the stab-in shoe which will rest on top of PBR. This collar will carry the liner weight avoiding the weight concentration in stab-in shoe lip. Modifying the profile of stab-in shoe lip is an option also. There is a need to make sure that the flat surface contact of the lip can carry the total liner weight.

5.6 Prevent Casing Damage

Multiple trips through the 13 3/8" casing caused the pipe to deteriorate each trip causing problems and a loss of rig time. Future work should be planned to minimize the number of trips and be careful not to damage the casing.

6. RESULTS

The well was subsequently flowed 19 days after the workover. A flowing PTS was conducted on day 26 after flow to verify if the cold zone was successfully isolated. The three steam zones above the unwanted zone at 3733' md were shown to be flowing (Figure 5). The PTS also revealed that the cold zone was no longer producing; instead, saturated fluid from the bottom is now flowing. This indicates that the workover was successful.

This was the first time that zonal isolation was done in Bulalo Field, and it is hereby being shared to the rest of the geothermal community to encourage further discussion and to refine the method used.

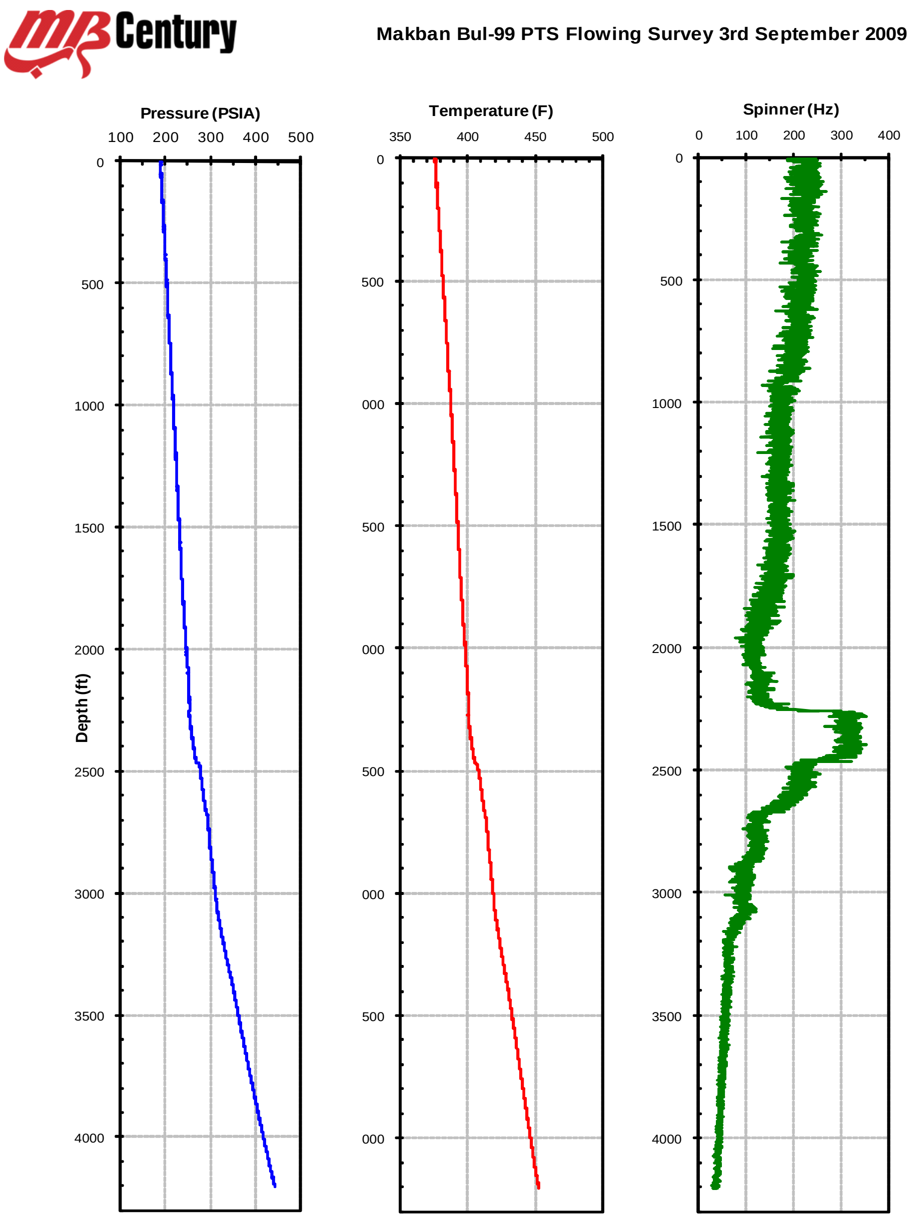

Figure 5: Bulalo-99 Flowing PTS on 03 September 2009 (After the Workover)