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A REVIEW OF MECHANICAL WORK-OVERS IN BACMAN AND MINDANAO GEOTHERMAL FIELDS, PHILIPPINES

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ABSTRACT

Mechanical work-over operations are an integral part of well rehabilitation to sustain steam supply to geothermal power plants. In the Bacman Geothermal Production Field (BGPF), mechanical work-overs have been conducted in ten out of fourteen production wells (70%), and four out of seven reinjection wells (60%). On the other hand, in the Mindanao Geothermal Production Field (MGPF), six production wells have been mechanically rehabilitated out of the total nineteen production wells (30%). In Bacman and Mindanao, the three major reasons for conducting mechanical work-overs include: casing or liner damage, mineral scale deposition, and cement-plugging of cold or acid feed zones. Preliminary assessment of the results of mechanical work-over jobs indicate that the success of the operation varies depending on the reason for well rehabilitation. Mechanical work-overs are effective in repairing wells with damaged casings, especially if the casings were relined. Simple milling operations are not so successful in restoring original well output. For wells that need to cement-plug cold or acid feed zones, mechanical work-over operations result to an expected decrease in well output because the plugged feed zones no longer contribute to total well discharge. Mechanical work-over operations yield variable results in wells with mineral scale blockages such as calcite and silica; though most were not able to restore original well capacity. Even in cases where an increase in well output occurred right after the work-over, recurrence of mineral scaling warranted additional mechanical work-overs or acidizing operations.

1.0 INTRODUCTION

Well rehabilitation is a necessary and continuing process to sustain steam production and supply to power plants for electricity generation in the four geothermal fields of the Philippine National Oil Company-Energy Development Corporation (PNOC-EDC). Well rehabilitation includes mechanical work-overs to remove blockages and obstructions inside the wellbore causing decline in output of production wells and in re-injection capacity of injection wells. Wells with damaged casings are relined with smaller-sized diameter casings and cemented to the surface. These methods utilize deep-penetrating drilling rig and bottomhole assembly in removing obstructions. Apart from mechanical work-overs, well rehabilitation may also include chemical treatment such as injection of acid to dissolve extensive and recurring mineral blockages.

This paper reviews the present scheme of mechanical work-over operations adopted by PNOC-EDC, and discusses results of mechanical work-overs in the BacMan (BGPF) and Mindanao (MGPF) geothermal fields.

2.0 PROCEDURES FOR MECHANICAL WORK-OVER

2.1 Drilling Assembly

A lean, normally slick bottomhole assembly is used for mechanical work-over operations to clear the borehole of any obstructions. The bit sizes vary from 8½ inches for the $9^5/_8$ inch-production casings, and 6¼ inches for the $7^5/_8$ inch-slotted liners. In case of casing damage, a milling tool is used. The drilling assemblies used for work-over operations are the following:

a. **8½" Clearing Assembly**: 8½" bit on junk sub on bit sub on 6½" drill collar on cross-over plus drill pipes

b. **6¼" Clearing Assembly**: 6¼" bit on bit sub on $4^3/_4$ " drill collar on cross-over plus drill pipes

c. **3½" Washing Tool**: 3½" wash tool on bit sub on $4^3/_4$" drill collar on cross-over plus drill pipes

d. **$8^3/_8$" Milling Assembly**: $8^3/_8$" flat bottom mill on four cross-overs on near bit stabilizer on 6½" spiral drill collar on short stabilizer on 6½" drill collar on cross-over plus drill pipes.

During work-over operations, normal drilling parameters applied for each assembly may range as follows:

Assembly	Weight on Bit (pounds)	Rotation per Minute
6¼" Clearing assembly	0 - 5000	35 - 50
$8^3/_8$" Milling assembly	2000 - 5000	50 - 95

2.2 Pre-Work-Over Operations

The well chosen for mechanical work-over is first cut-off from the steam production line. After the drilling rig is set-up over the well, quenching operations will begin using fresh water. The wellhead is removed to install the blow-out preventer (BOP). The master valve is closed but a minimum flow with killing/quenching rate is maintained. The wellhead is torn down and the master valve replaced with service master valve while continuously pumping at minimum quenching rate through the side valve.

2.3 Actual Work-over Procedures

a. An 8½ inch-diameter clearing assembly is run-in to remove any obstruction; if obstruction persists, an 8 inch-diameter impression block will be used to determine nature of the blockage.

b. Impression on the block is assessed for possible casing collapse or break; in case of casing collapse, casings are enlarged using various mills and swage. If casings are damaged, on the other hand, milling tool is used to smoothen out damaged portions of the casings.

c. An 8½ inch-diameter bit with installed junk sub is run-in on top of the liner to recover any mineral or rock samples for identification.

d. A 6½ inch-diameter bit is used to clear the $7^5/_8$ inch-diameter liners down to bottomhole. Liners are washed with fresh water from top to bottom with required pressure and flowrate.

e. After pulling-out the clearing assembly, completion tests are conducted.

3.0 CHOOSING WELLS FOR WORK-OVER

A significant decline in steam output of a production well, or in injection capacity of a reinjection well, signals the need for work-over operations. Outputs of production wells are continuously monitored using flow-meter apparatus installed in the power plant. Physical well parameters are measured such as wellhead pressure, enthalpy, water and steam flows. These well data are compared with chemical analysis of gas and brine discharges as well as with on-line Tracer Flowline Tests (TFT) measurements of flow rates of steam and separated brine.

Wells with high potential for mineral scale deposition are determined from well chemistry which shows fluid saturation for calcite and silica, common scale minerals found in geothermal wells. Wells with calculated mineral saturation index higher than 1.4 are considered possible candidates for work-over operations.

Finally, downhole surveys are conducted in wells with declining performance to determine presence of mineral blockages or other problems related to physical conditions of the well. All of these data are then presented and discussed in a technical meeting between geoscientists, reservoir engineers, drilling engineers and site production group. A conclusion will be reached whether a work-over operation is warranted, followed by submission of recommendation to higher management including costs and duration of work-over. Upon approval of the recommendation, a drilling rig is sourced-out and scheduled for the work-over operations.

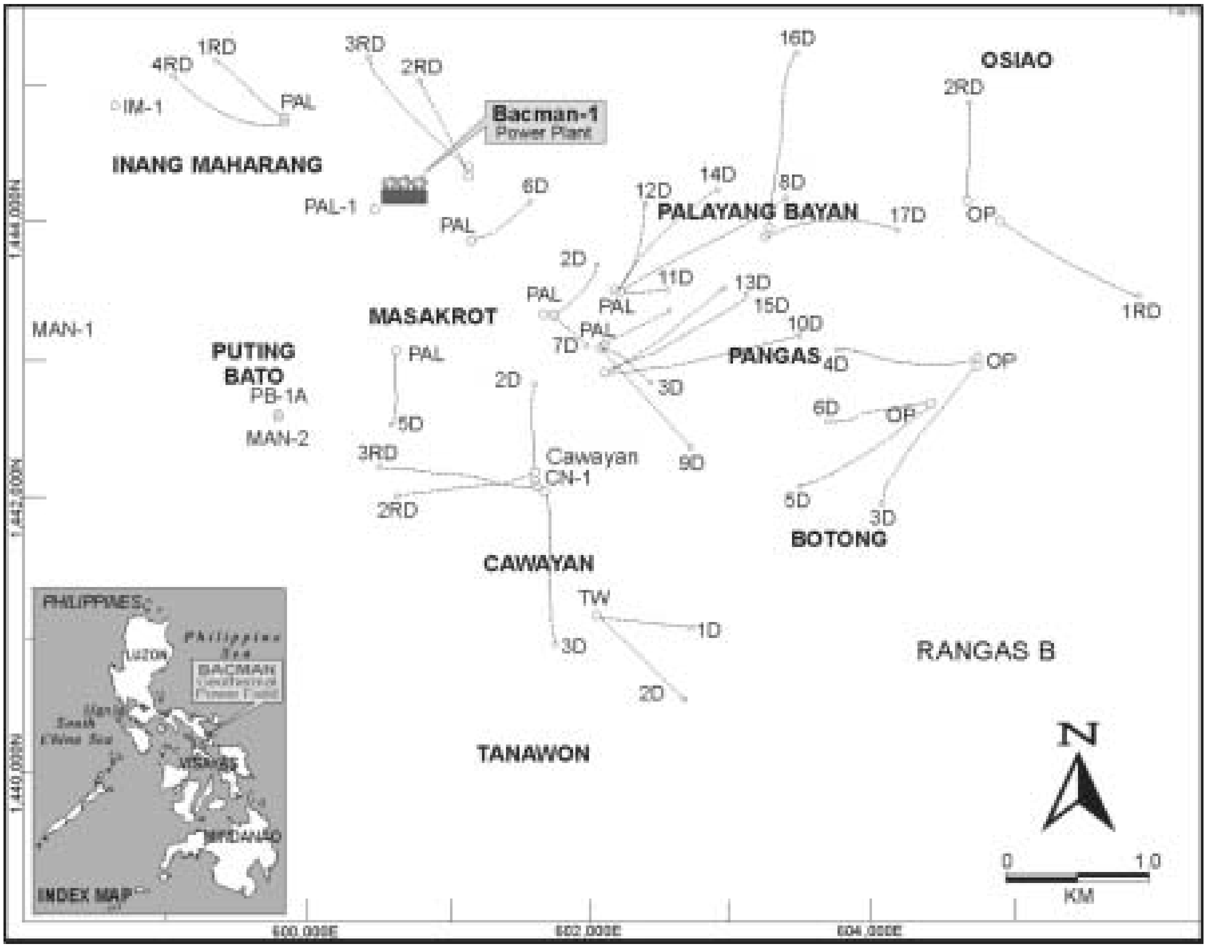

Figure 1. Location of production and reinjection wells in Bacman Geothermal Production Field.

4.0 RESULTS OF MECHANICAL WORK-OVERS

4.1 BacMan Geothermal Production Field (BGPF)

Located in Southern Luzon, the BacMan Geothermal Production Field (BGPF) has been operating its 110 MWe power plant (Bacman 1) since 1993. A total of fourteen production wells are presently hooked-up to the power plant (Fig. 1). Out of these 14, ten wells (70% of total) have already undergone mechanical work-over operations (Table 1). On the other hand, among the seven reinjection wells used for disposal of waste brine, four wells (60% of total) have been worked-over.

Table 2 summarizes the results of mechanical work-over operations conducted in BacMan 1. Among the production wells, work-over was done for two reasons: repair of casing damage; and clearing of mineral blockages, mainly calcite. Out of the ten production wells that were worked-over, five wells had damaged casings; while the other five suffered mineral scale deposition. Preliminary evaluation of the results indicate that the success ratio of mechanical work-over operations was variable for wells with mineral scales as well as those with casing damage (Table 2).

Out of the five production wells with calcite blockages, two wells (Pal-9D and Pal-21) were able to increase their output ~15% from the original value right after the work-over. With time, however, their output still manifested a continuous decline due to recurrence of mineral scale deposition. Thus, well Pal-21 underwent two more mechanical work-overs after a period of four years. On the other hand, acidizing operations were conducted in well Pal-9D to dissolve calcite scales.

Table 1. Total wells vs. mechanical work-over jobs.

Production Field	Total Production Wells	Mechanical Work-overs	Total Reinjection Wells	Mechanical Work-overs
1. BacMan 1 (110 MWe)	14	10	7	4
2. Mindanao				
a. M1GP (52 MWe)	10	3	5	0
b. M2GP (52 MWe)	9	3	2	0

Table 2. Results of mechanical work-overs in BacMan.

	Mineral Blockage	Casing/Liner Damage	Formation Collapse
A. PRODUCTION WELLS			
1. Pal-3D	-36%		
2. Pal-4D	-18%		
3. Pal-9D	+15%		
4. Pal-11D		-33%	
5. Pal-12D		+9%	
6. Pal-13D	-4%		
7. Pal-14D		-3%	
8. Pal-19		+2%	
9. Pal-20D		+4%	
10. Pal-21	+17%		
B. REINJECTION WELLS			
1. Pal-2RD			-100%
2. Pal-3RD	+118%		
3. Pal-6D		-3%	
4. IM-1		+1%	

*results expressed in percentage increase or decrease in output/capacity

The other three wells (Pal-3D, Pal-4D, Pal-13D) were not able to regain their original output even after mechanical work-over. Well Pal-3D was acidized last year; while Pal-4D has been scheduled for acidizing operations. Well Pal-13D, on the other hand, had to undergo another mechanical work-over because its slotted liner was damaged during the first work-over.

The five production wells with casing damage are Pal-11D, Pal-12D, Pal-14D, Pal-19 and Pal-20D. After mechanical work-over, three wells (Pal-12D, 19, 20D) whose casings were relined were able to regain their original output. In the other two wells (Pal-11D, 14D), milling operations were conducted to repair the casings. Unfortunately, they were not successful in restoring original output of these wells.

In the case of reinjection wells, reasons for mechanical well rehabilitation include casing or liner damage, mineral blockage and formation collapse. As in the production wells, results of mechanical work-overs in reinjection wells vary.

Well Pal-2RD, which suffered formation collapse, was not able to regain its original injection capacity. After work-over, the well no longer accepts injected fluids. On the other hand, mechanical work-over was able to clear silica blockages in well Pal-3RD increasing its injection capacity by more than 100%. However, declining capacity of Pal-3RD with time indicates recurrence of silica deposition. This well will be scheduled for another mechanical work-over if its injection capacity declined significantly to affect waste brine disposal in Bacman 1.

Well IM-1 was able to regain its original injection capacity after its damaged casing was relined. On the other hand, milling operations to repair damaged liner of well Pal-6D were not so successful in restoring original well capacity.

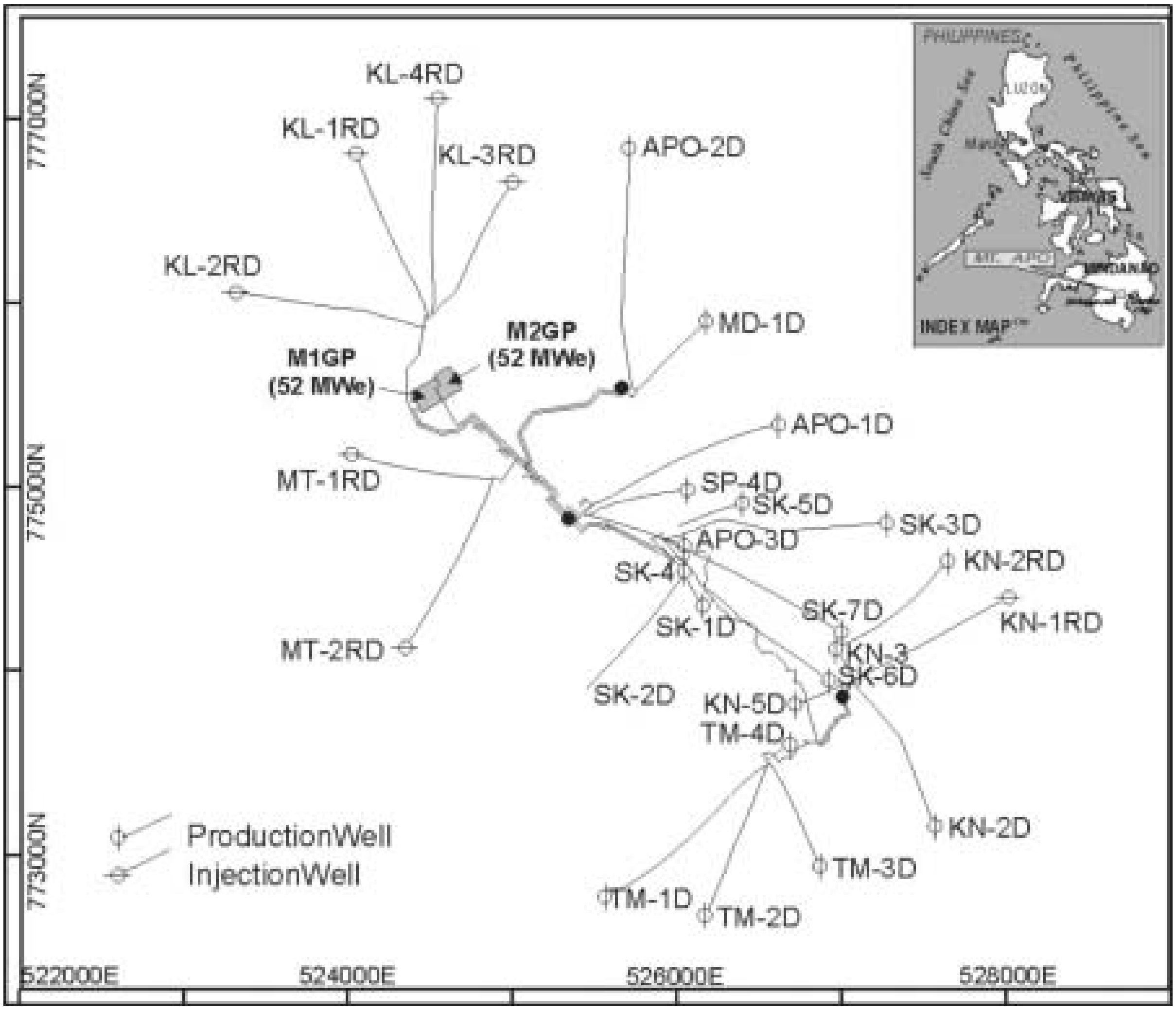

Figure 2. Location of production and reinjection wells in Mindanao Geothermal Production Field.

4.2 Mindanao Geothermal Production Field (MGPF)

The Mindanao Geothermal Production Field is made up of two 52 MWe power plants with a total of nineteen (19) production wells and seven (7) reinjection wells (Fig. 2). Thirty percent or six out of the 19 production wells have been rehabilitated by mechanical work-over operations (Table 1).

In the MGPF, production wells underwent mechanical work-over for four reasons: a) cement-plugging of cold or acid feed zones; b) mineral scale deposition; c) casing break; and d) mud damage.

Table 3 shows the results of these mechanical work-over jobs in Mindanao. Two production wells (APO-1D, APO-2D) needed to plug their bottom feed zones where cold fluids are entering; while well KN-1D had to isolate its bottom acid zone. In all cases, post-work over tests revealed an expected decrease in well output due to cement-plugging of feed zones which previously contributed to the well discharge.

A casing break warranted a mechanical work-over in well KN-2D; but the well's original performance was not successfully restored. On the other hand, mechanical work-over was able to enhance permeability of well TM-1D which was damaged by large amounts of mud pumped into the well during drilling.

In well SP-4D, mechanical work-over was able to clear the calcite blockage which caused its

Table 3. Results of mechanical work-overs in Mindanao.

	Mineral Blockage	Casing Damage	Cement-plugging of Cold/Acid Zones	Mud Damage
A. Mindanao 1 (52 MWe)				
1. APO-1D			-40%	
2. APO-2D			-14%	
3. SP-4D	+32%			
B. Mindanao 2 (52 MWe)				
1. KN-1D			-52%	
2. KN-2D		-18%		
3. TM-1D				+10%

*results expressed in percentage increase or decrease in output/capacity

output to decline to less than 1MWe. After the work-over, a ~10% increase in well output was recorded.

5.0 SUMMARY AND RECOMMENDATIONS

In Bacman 1, mechanical work-over operations were conducted in ten out of fourteen production wells (70%), and four out of seven reinjection wells (60%). In Mindanao, on the other hand, six production wells were mechanically rehabilitated out of the total nineteen production wells (30%).

The three major reasons for conducting mechanical work-overs in Bacman and Mindanao include: casing or liner damage, mineral scale deposition, and cement-plugging of cold or acid feed zones. Other reasons for well rehabilitation are formation collapse and mud damage.

Results of mechanical work-over jobs vary depending on the reason for well rehabilitation. Mechanical work-overs are effective in rehabilitating wells with damaged casings, especially if the casings have been relined. In these cases, original output and capacity of wells are regained. However, simple milling operations are not so successful in restoring original well output.

For wells that need to isolate cold or acid feed zones, a decrease in well output is expected because of the loss of feed zones which previously contributed to the total well discharge.

For wells with mineral scale blockages such as calcite and silica, mechanical work-over operations yield variable results, though most were not able to restore original well capacity. In some wells, an increase in output or capacity occurred right after mechanical work-over. Nonetheless, well output later declined with time due to recurring mineral deposition requiring additional mechanical work-overs or acidizing operations.

Mechanical work-over operations will remain to be an integral part of well rehabilitation to sustain steam supply to geothermal power plants. To further improve success of mechanical work-overs, the following are recommended:

- Use a smaller but mobile rig, possibly truck-mounted, which is capable of clearing borehole down to ~1500 m MD, the optimum setting depth of 9-5/8” production casing shoe. Also, a smaller rig can be set-up faster.

- Use medium temperature-capable camera to probe obstructions inside the well bore such as mineral deposits or casing bulges. After knowing nature of obstruction, proper utilization of bottomhole assembly can be determined. This will minimize over-application of weight on bit, and protect the casings from irreparable damages during clearing.

- Use special contraption or gland for clearing obstructions in flowing wells as done in Iceland. This will minimize cutting-off the well from the steam line and needs less than a week to put the well back to production.