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PREVENTION AND CONTROL OF CALCITE DEPOSITION IN TWO-PHASE HEADER: THE BACMAN-2 BOTONG EXPERIENCE

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ABSTRACT

A liquid removal system (LRS) was installed along the two-phase branchline of well OP-5DA, which is composed of a modified 610-mm diameter oversized drain pot (ODP) and a 457-mm diameter standard drain pot (SDP). The objective is to prevent calcite deposition inside the header by collecting and draining OP-5DA's liquid component before it mixes with well OP-6D fluids at the 610-mm diameter two-phase line header.

Prior to the installation of the LRS, massive calcite deposited six meters in length from the mixing point and fully blocking the 610-mm header within a ten-month period. The calcite deposits of about 1.63 m³ gave an equivalent calcite deposition rate (CDR) of 0.163 m³/month. With the LRS installed, about 52% reduction in the CDR or 0.084 m³/month was observed after pipe inspection. Further revisions on the LRS and its operation led to a significant decline in CDR by 83% or 0.027 m³/month as compared with that without LRS.

Previous physical and chemical simulations show that the cause of calcite deposition inside the header is due to mixing of incompatible fluids from OP-5DA and OP-6D. OP-5DA high-enthalpy two-phase fluid is supersaturated with respect to calcite, while that of OP-6D is pure steam and superheated by as much as 16°C. As these fluids mix, further boiling occurs resulting to voluminous calcite deposits formed at the mixing point in the header. Removal of OP-5DA liquid component with an ODP was chosen to be an economical solution among the options.

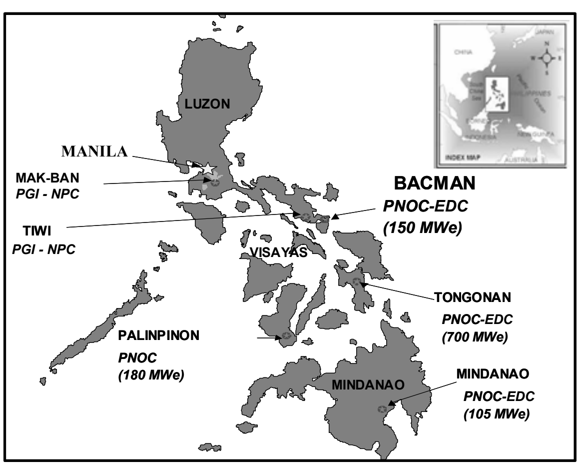

Figure 1. Philippine map with Bacon-Manito geothermal production field.

1.0 INTRODUCTION

The Bacon-Manito Geothermal Production Field (BGPF) is located on the southernmost part of Luzon island, Philippines (Fig. 1). It is situated at the boundaries of the towns of Bacon, Sorsogon and Manito, Albay. BGPF has three commercially operating geothermal power plants: BacMan I in Palayang Bayan sector with a 110 MWe (2 x 55) and BacMan II in Cawayan and Botong with a 1 x 20 MWe Modular Power Plant each (Fig. 2). These were respectively commissioned in 1993, 1994 and 1998.

Calcite scaling deposition in the wellbore has been commonly experienced in Philippine geothermal fields and remedied by mechanical clearing and injection of a chemical inhibitor into the well.

In BacMan II Botong sector, calcite deposition inside a two-phase pipeline header was experienced and reported previously by Fragata (1999) and Solis, et al (2000). This has been a rare case and the first experience in Philippine geothermal fields. This report presents the experiences in controlling calcite scale in two-phase line through physical method using the liquid removal system (LRS).

2.0 BACKGROUND

During the initial field operation in 1998, Botong had four production wells supplying steam to the power plant: OP-3D and 4D at Pad-BA and OP-5DA and 6D at Pad-BB. OP-7D at Pad BB was later put on-line in 1999. The set-up in Botong is shown in Figure 3. The Botong system consists of wells individually transmitting two-phase fluids through a 457-mm diameter branchline. In both Pads BA and BB, the two-phase fluids in the branchlines enter a 610-mm diameter header, and conveyed through a 762-mm diameter pipe before entering the lone separator. The separated steam goes to the power plant via a 762-mm diameter steam line while the separated liquid is flashed atmospherically and injected at low temperature by gravity. It is worthwhile to note that Geogard SX (GSX), a silica deposition inhibitor, is being injected at a two-phase branchline header at Pad BA.

The calcite deposition problem was initially manifested by simultaneous and abnormal increases in wellhead and branchline pressures of OP-5DA and OP-6D after eight months (March - November, 1998) of utilization. Inspection in February 1999 revealed that the cause of pressure increases was due to calcite scale deposits formed at the mixing area of OP-5DA and OP-6D at the header (Fig. 4). Bulk of the deposits occurred within a six-meter length header downstream from the mixing point with a calculated volume of 1.63m^3 within a 10-month period. The deposition rate is about 0.163m^3 per month. The calcite scale thickness declines further downstream in corral-like formation. Petrography analysis of the scale deposits (Ramos, 1999) indicates 82% calcium carbonate (calcite), 15% amorphous silica and 3% impurities (Fig. 5). Thin platy calcite crystal and laminates were also observed at the bottom of OP-5DA branchline (Fig. 6).

Previous physical and chemical simulations (Solis, et al., 2000) indicate that the steam-dominated fluid of OP-5DA is supersaturated with respect to calcite, while that of pure-steam discharge of OP-6D is superheated by 16°C. As both fluids mix, boiling and volatilization occur, thus further increasing the calcite supersaturation. The mixing and further boiling processes contributed significantly to the voluminous calcite scale deposits at the mixing point at the header.

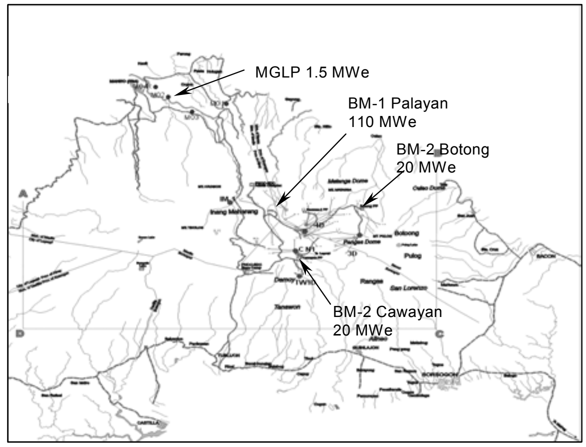

Figure 2. Bacon-Manito geothermal production field sectoral distribution.

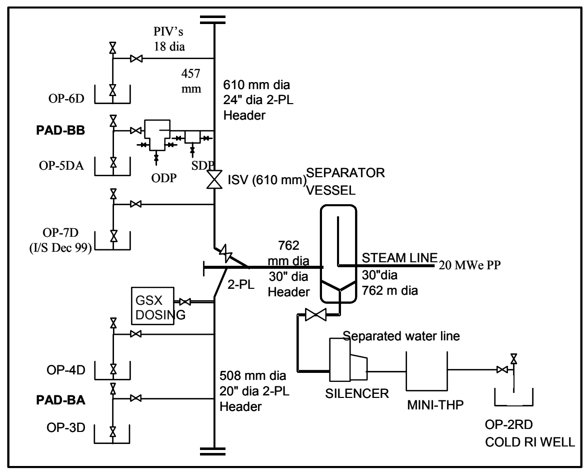

Figure 3. Botong Fluid Collection and Disposal System (FCDS) schematic diagram.

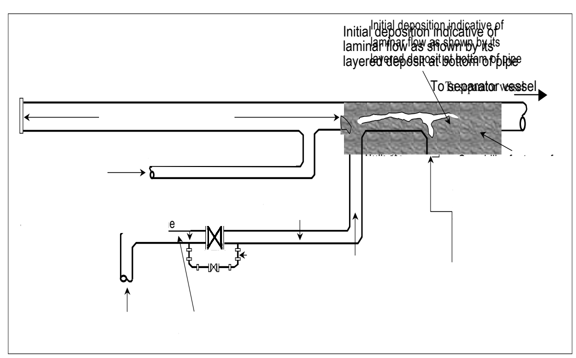

Figure 4. Botong Pad-BB FCDS inspection (February 1999).

Figure 5. The 610-mm diameter header where fluids of OP-5DA and OP-6D mix. The main blockage area.

Figure 6. OP-5DA branchline with platy calcite.

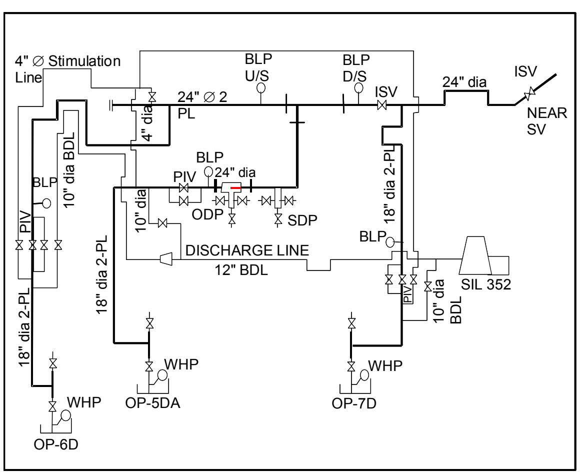

Figure 7. BM-2 Botong Pad-BB modified FCDS configuration with well OP-7D put in-service on Dec. 1999.

The two-phase line calcite deposition problem resulted in load reductions effected by limited steam supply. On 5-8 February 1999, the whole FCDS was shutdown to install the 610-mm diameter isolation valve (ISV) at Pad BB header. OP-3D and OP-4D supplied steam to the plant after the ISV was installed with limited load. Load increased when OP-6D was cut-in on 12 February 1999 after replacing the blocked header with another 610-mm diameter pipe as a temporary solution. OP-5DA was cut-in on 8 June 1999 via its 4-inch diameter stimulation line towards the header to increase steam supply. Using this system, similar calcite scale deposits again occurred exactly at the mixing point of OP-6D and OP-5DA fluids at the two-phase line header.

Total generation loss associated with the calcite scale problem was 6,034.97 MWh or an equivalent of P3,439,933.00 computed at a base price of P0.57/kWh (excluding inflation factor).

Several options were then considered to remedy the problem:

a) Allow deposition in spools while maintaining the spools as required.

b) Remove OP-5DA liquid component.

c) Lower the superheated fluid of OP-6D to saturation condition through heat transfer.

d) Injection of a chemical inhibitor.

Operational and economic considerations indicate that removal of OP-5DA liquid component is the most economical option using an ODP.

3.0 LIQUID REMOVAL SYSTEM (LRS) DESIGN

The LRS is composed of a modified oversized drainpot (ODP) and a standard drainpot (SDP) installed along OP-5DA's branchline (Fig. 7). The ODP will collect and drain the OP-5DA liquid component prior to mixing with OP-6D fluid at the header.

The ODP is composed of a T-shaped 610-mm diameter outer pipe assembly with a 610-mm diameter catch pot at the bottom and an inner

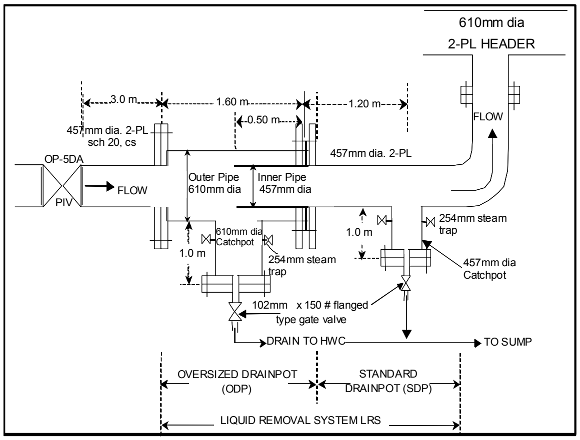

Figure 8. Well OP-5DA Liquid Removal System with its ODP and SDP

Figure 9. OP-5DA ODP and SDP actual set-up

457-mm diameter pipe assembly (Fig. 8). The outer pipe is flanged at both ends and is spooled to a cut section of the 457-mm diameter branchline. The inner pipe located downstream is shorter than the outer pipe and is concentrically flanged with the outer pipe thus providing a gap where liquid passes, falls by gravity and collected at the catch pot below.

The gap length is computed so that the momentum of the liquid is not enough for the liquid to touch the rim of the inner pipe. A wavy or stratified flow upstream of the ODP must be ensured. Under this condition, most of the vapor phase will flow directly into the inner pipe with a minimum turbulence and, hence, pressure drop. There may be conditions where liquid carry-over will occur but the piping configuration is designed so that this carry-over will be collected outside the inner pipe and into the flange surface of the inner pipe and eventually creep down into the pot.

The catch pot is sized and designed such that vortex formation is averted and live steam discharge is avoided. Two sets of thermodynamic steam traps are installed in the catch pot to discharge the collected liquid while sealing-in the steam.

Downstream of the ODP is a 457-mm diameter T-shaped standard drainpot (SDP). This is eccentrically flanged connected with the branchline with installed steam traps to discharge carry-over liquid that may have escaped the ODP. Both ODP and SDP had 0.51-mm diameter valve bottom drains. The actual set-up of the liquid removal system is shown in Figure 9.

System efficiency was gauged in terms of the reduction of the volume of calcite scale deposited at the header before and after installation of the LRS.

4.0 LRS UTILIZATION

The LRS was commissioned on 30 August 1999 and used until 21 March 2000 (6.77 months) with both OP-5DA and OP-6D simultaneously in-service to the system. For almost two months from September to October 1999, the LRS was continuously draining liquid from its thermodynamic steam traps. From November 1999 to March 2000, however, liquid discharges became intermittent. The bottom drains could not be opened at the time due to several constraints.

During the power plant shutdown for cooling tower fan repair on 22 March to 8 April 2000, several revisions were made on the LRS. The area and cellar within the LRS was enlarged for easier maintenance. The steam traps and bottom drains of the ODP were replaced with 101-mm diameter drain valves. These were kept continuously opened during operation to prevent clogging. Pipes were added connecting the drain valves to a discharge canal. A weirbox along the discharge canal was installed for water flow measurements to determine liquid removal efficiency. On 9 April 2000, the LRS was again utilized with its new drain system until it was

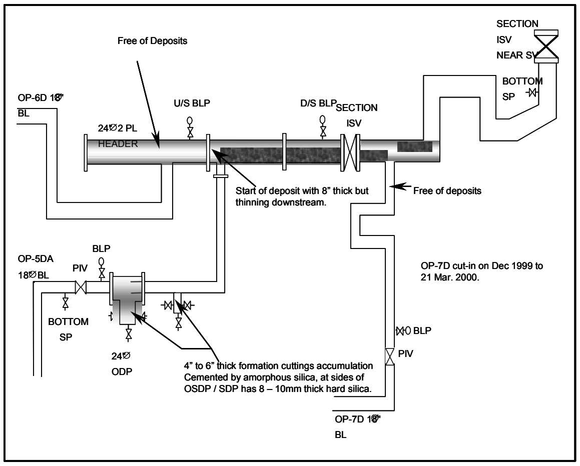

Figure 10. Pad BB FCDS inspection after initial use of the LRS installed at OP-5DA branchline

shutdown on 14 May 2001 due to the scheduled power plant preventive maintenance and servicing. Since the revision of the ODP, the LRS has been continuously in operation for 13.3 months.

5.0 INSPECTION RESULTS

The inspection conducted during power plant shutdown in March 2000 revealed the recurrence of calcite scale deposits in the header (Fragata, 2000). The deposition occurred exactly at the mixing point of OP-5DA and OP-6D fluids, similar with that of the previous experience (Fig. 10). The calcite deposition, though is not as voluminous as in the previous inspection, has only 203-mm thick deposit (thickest section) at the bottom of the pipe but with minimal deposits at the top and sides portion. Again, bulk of the deposits occurred within the six-meter length of the header. The calculated volume of the deposits was 0.572 m^3.

Inspection of the OP-5DA branchline from its production isolation valve to the header showed, however, silica deposits and not platy calcite crystals as previously observed. The silica deposits though are very minimal at 5-mm thick were only at the bottom of the pipe. The silica deposition along OP-5DA BL with LRS was due to flashing of fluid as it passes thru the ODP/SDP. The fluid flashing caused the temperature to drop, which tend the fluid to be oversaturated with respect to silica.

The OP-6D branchline and the header section upstream of the deposits are generally free of deposits, same as previously observed.

At the ODP and SDP, the bottom drains showed accumulations of formation cutting materials cemented by silica. The walls of the ODP and SDP have 10-mm thick silica deposits. These deposits caused the clogging of steam traps and bottom drains, and, hence, the intermittent and non-discharges after extended usage.

The clogged steam traps allowed the accumulation of liquid inside the catch pot. The condensate became supersaturated with respect to silica as the fluid cools down and eventually cemented the cuttings. The cemented cuttings resulted in a flooding of the catch pot and reaching a water level probably as high as the bottom of the inner pipes resulting in silica deposition at the bottom of the branchline. The drains and operating procedures have since been adjusted to prevent a similar recurrence of the situation.

Pad-BB FCDS was again inspected on 23 May 2001, after 13.3 months of LRS utilization, during the power plant PMS shutdown on 14 May 2001. Inspection revealed the recurrence of calcite scale deposits but was significantly reduced with only 127-mm at the thickest portion of the deposit within the same 6-m length deposition area. This indicates the effectiveness of the revision made on the LRS draining system.

The 610-mm header exactly opposite OP-7D branchline, however, showed thicker calcite deposits of about 457 mm. It was deduced that a similar process occurred as observed in OP-5DA and OP-6D. OP-7D branchline is observed generally free of any calcite scale deposits.

Well OP-7D was cut-in to the system on 9 December 1999 after its work-over and acidizing operation on 23 June – 5 July 1999. It was acidized due to its mud-damaged permeable production zones. Calcite saturation indices using WATCH program simulation (Bjarnasson, 1994) revealed that OP-7D discharge fluids were initially under saturated with respect to calcite. With time, its fluid became supersaturated with similar characteristics as OP-5DA. The calcite scale deposition process at the header with OP-7D on-line is the same as previously experienced with OP-5DA and OP-6D.

A similar liquid removal system will be installed along OP-7D's 457-mm diameter branch line.

6.0 WEIR WATERFLOW DISCHARGES

After the LRS revision, liquid removal is now on a continuous basis. Corrected weir water flow measured is in the range of 0.5 to 2.0 kg/s. This water flow is comparable with OP-5DA's water flow measured from the bore output measurements and Tracer Flow Tests. Latest pipe inspection on May 1, 2001 showed minimal scale deposits of 127-mm maximum at the thickest portion at the header. A CDR of about 0.028 m^3/month was calculated after the LRS draining system was revised. The system has been running for almost 14 month of straight utilization.

7.0 CONCLUSIONS

The LRS was successful in controlling calcite scale deposits at the 610-m diameter header. The ODP installed along the two-phase branchline of OP-5DA was successful in its purpose of removing the liquid component of the discharge fluid. This was confirmed by significantly reduced volume of calcite scale deposits observed during pipe inspection. The deposition rate without the LRS was 0.163 m^3 per month and was significantly reduced by about 83% to 0.028 m^3 per month with the installation and further modification of the ODP.

To operate the LRS to its optimum efficiency, a regular de-clogging of the ODP and SDP drains have to be religiously followed for continuous liquid removal.

ACKNOWLEDGEMENTS

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