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CONQUERING THE CHALLENGES IN GEOTHERMAL UTILIZATION – THE EDC EXPERIENCE

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ABSTRACT

Energy Development Corporation (formerly PNOC-EDC) continues to lead the Philippines and the World in harnessing geothermal energy for power generation 32 years after it was founded. This paper highlights some of EDC's experience and expertise in sustaining production of its geothermal fields which were anchored on the adopted practices and developed practical technologies to help manage its geothermal resources: 1) Tracer tests refined injection strategies to comply with environmental regulations and optimize recharge to the reservoirs; 2) Limitations dictated by fluid chemistry were addressed by studies geared towards inhibiting deposition of calcite and amorphous silica; 3) Measures to capture suspended solids in steam-dominated discharges mitigated damages to surface facilities; 4) On-line steam purity monitoring ensured constant delivery of good quality steam to the power plants. Adept management of EDC's geothermal fields is a key factor that boosted investor confidence leading to the company's highly successful initial public offering in 2006 and full privatization in 2007. EDC aims to expand its horizon by developing an additional 310 MWe of geothermal power by 2015, pursue acquisitions of government-owned geothermal power plants and increase international cooperation in geothermal services, consultancy and drilling projects**.**

1. INTRODUCTION

At the forefront of Philippine geothermal development is the Energy Development Corporation (EDC), a leading energy company fully-privatized in 2007 after three decades of operating as a subsidiary and geothermal arm of the government-owned and controlled Philippine National Oil Corporation (PNOC). As of 2008, EDC operates a combined capacity of ~1,200 MWe from its geothermal steamfields (Figure 1) in Leyte (Leyte geothermal production field or LGPF), Negros Oriental (Southern Negros geothermal production field or SNGPF), Negros Occidental (Northern Negros geothermal production field or NNGPF), Bicol (Bacon-Manito geothermal production field or BGPF) and North Cotabato (Mindanao geothermal production field or MGPF) accounting for more than 60% of the country's total geothermal capacity. EDC's journey towards making the Philippines the second largest producer of geothermal energy in the world (next only to the United States) involves hurdling some of the challenges that beset commercial exploitation of geothermal energy. This paper discusses some of the solutions developed by EDC aiming to sustain the steam production of the geothermal fields through prudent injection strategies (tracer tests) and to optimize utilization of the geothermal fluids by addressing obstacles encountered in the wellbore and surface facilities (scale inhibition, solids mitigating measures and on-line steam purity monitoring).

2. TRACER TESTS

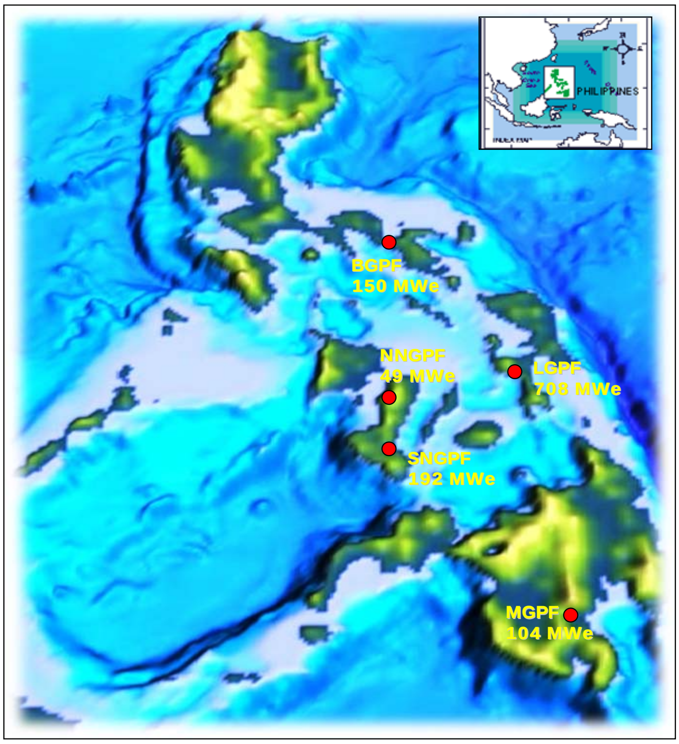

FIGURE 1: Geothermal fields of EDC

Geothermal field operations are mandated by strict Philippine environmental laws to achieve zero effluent disposal thus it is imperative for EDC to inject geothermal fluids (separated brine and power plant condensate) back into the reservoirs. With continuous commercial exploitation, injection becomes an essential aspect of reservoir management, serving as pressure barriers against the inflow of cooler peripheral fluids as a consequence of field pressure drawdown. The detrimental effect of the injected fluids returning back to the production sector is a calculated risk evaluated by EDC through extensive tracer testing in its geothermal fields since the early 80's (Urbino et al., 1986) as discussed in the works of Nogara and Sambrano (2005) in MGPF, Herras et al. (2005) in Mahanagdong sector of LGPF, Maturgo et al. (2006) in SNGPF, Dacillo and Herras (2008) in Upper Mahiao sector of LGPF and Olivar et al. (2008) in Tongonan-1 sector of LGPF (Table 1). EDC has worked with various tracers that include sodium fluorescein, Iodine-125, Iodine-131 and naphthalene disulfonate (NDS) which is widely used due to is low level of detectability and stability at high temperatures. With the transformation of some EDC fields from liquid- to steam-dominated reservoirs, the utilization of vapour tracers (Tritium and HFC) are underway through the Coordinated Research Program with the International Atomic Energy Agency. Interpretation of the tracer data such as quantification of fluid flow and well cooling predictions were done using mainly the TRINV (Arason, 1993) and TRCOOL (Axelsson et al., 1993), respectively, in the ICEBOX software package (UNU-GTP, 1994) and recently with the Anduril software by Maggio of Noldor, Inc.

TABLE 1: Tracer tests conducted in EDC fields.

Field	Injection date	Tracers used	Objective
MGPF	2003	1,6 NDS / 2,6 NDS	Evaluate injected brine returns from Matingao and Kullay sectors
LGPF	2003	1,5 NDS / 1,6 NDS / 2,6 NDS	Define flow paths of inflowing cooler peripheral waters and brine injected in Mahanagdong sector
LGPF	2003	1,5 NDS	Evaluate condensate returns injected in Upper Mahiao sector
SNGPF	2005	1,5 NDS / 1,6 NDS	Evaluate brine returns injected in Palinpinon-II sector
LGPF	2006	1,6 NDS	Evaluate brine returns injected in Upper Mahiao sector
LGPF	2006	1,5 NDS / Tritium	Evaluate brine returns injected in Tongonan-1 sector
LGPF	2007	1,5 NDS / 2,6 NDS / 2,7 NDS	Evaluate brine returns injected in Malitbog sector

The results of the tracer test, in conjunction with geochemical monitoring and reservoir engineering data, allowed formulation of beneficial injection strategies. For instance, the multi-tracer test in the Mahanagdong sector of LGPF resulted in the following measures (Figure 2): (1) diversion of power plant condensate injection away from the production sector, (2) optimum separated brine loading in Mahanagdong-B to provide hotter recharge and block the migration of groundwater from the west and (3) optimum separated brine loading in Pad MGRD1 to balance the detrimental effect of cooling with the beneficial effect of providing recharge and reducing the calciting potential of some production wells affected by brine returns.

The results of the tracer tests also provided information in addition to reservoir simulation and modelling to refine existing hydrological models and predict future reservoir responses at various extraction and injection scenarios as demonstrated by Amistoso et al. (1990) and Esberto et al. (2001). The tracer tests complement the geochemical and reservoir monitoring allowing EDC to devise action plans to address anticipated problems in the future implementation of expansion projects such as the 20 MWe Nasulo optimization in Palinpinon-II of SNGPF and the 50 MWe "Greenfield" projects in MGPF.

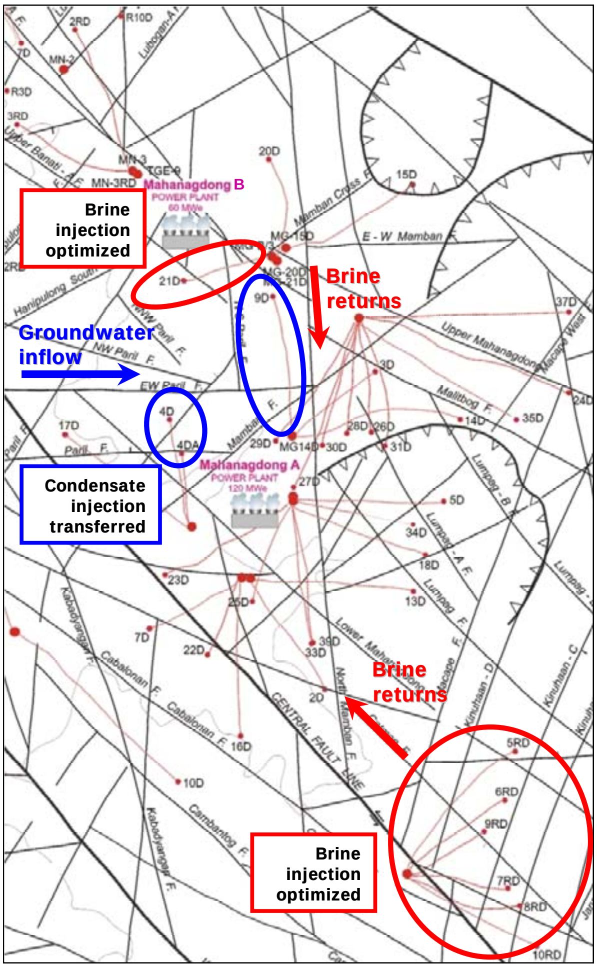

FIGURE 2: Injection strategies in LGPF Mahanagdong sector

3. MINERAL SCALING

3.1 Calcite inhibition

Some production wells in the EDC geothermal fields are affected by calcite deposition in the wellbore as also experienced in some fields worldwide. Mechanical clearing with acidizing using a drilling rig was previously conducted to recover the well outputs. But this method proved uneconomical, could not prevent further calcite deposition and thus its recurring procedure increases the risk of damaging the production liners. Since 1999, EDC adopted a calcite inhibition system (CIS) to sustain the outputs of calciting wells in MGPF (Nogara et al., 2001 and Dacoag et al., 2005), LGPF (Siega et al, 2005), BGPF and NNGPF. The CIS set-up introduces a chemical calcite inhibitor below the expected flash point of the well by using a capillary tubing thereby reducing significantly the decline rate in well mass flow caused by calcite blockages and extending the well's productive life.

FIGURE 3: CIS set-up in well APO-1D (MGPF)

Evaluations of two critical factors for a successful CIS set-up were developed by EDC through its manpower expertise and experience. First, the determination of the well's flash point depth, which dictates the calcite inhibitor injection depth, is accurately achieved by obtaining pressure and temperature survey data used to model wellbore characteristics with the aid of simulation tools. Run-in and maintenance of the capillary tubing is handled by experienced well logging service crews. Second, the suitable inhibitor and the system for injecting it into the well are carefully chosen based on the well's physical and geochemical characteristics and the results of in-house procedures to test the inhibitor's thermal stability and calcite inhibition efficiency (NACE test). Calcite inhibitors successfully used by EDC are polymeric types with carboxylic functional groups.

3.2 Silica inhibition

EDC undertook various measures to cope with the problems of amorphous silica scaling in the exploitation of its different geothermal fields other than by simple limiting of operating pressures (and consequently well outputs) to avoid silica-supersaturated conditions. These include brine pH modification through acid treatment, polymerization experiments and evaluation and use of chemical inhibitors (Garcia et al., 1996; Baltazar et al., 1998; Mejorada et al., 2001; Alcober et al., 2005; Angcoy et al., 2005a; Panopio et al., 2008; Remoroza et al., 2008 and See, 2008). The methods and studies were varied and suited depending on the brine chemistry of the field such that pilot test set-ups (such as shown in Figure 4) were designed to replicate actual conditions addressing silica scaling either in surface facilities or in wellbore formation that decreases acceptance of injection wells. The pilot test set-ups can also be utilized to evaluate the efficiency of different chemical inhibitors and gauge their suitability to field operations thereby saving significant costs prior to actual applications. Silica scales induced when using different kinds of silica scale inhibitors can be characterized in EDC's petrology laboratory to evaluate their acceptability to present operations.

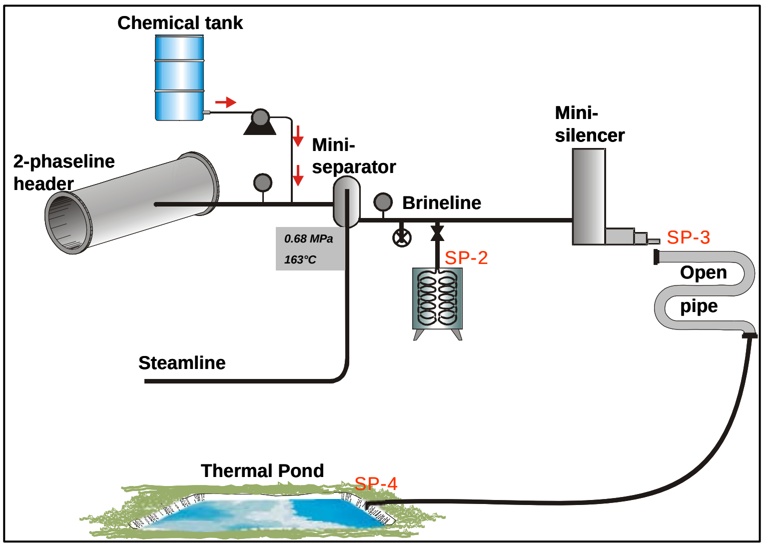

FIGURE 4: Silica inhibition set-up in Botong sector, BGPF (Panopio et al., 2008)

The results of the different silica inhibition studies allowed EDC to overcome limitations to energy conversion from geothermal fluids thereby maximizing power generation translating to the successful operation of the 14.7 MWe Malitbog bottoming cycle plant and 4.6 MWe Upper Mahiao brine OEC power plant in LGPF; the 20 MWe Botong power plant in BGPF; and the future development of the 20 MWe optimization project of Nasulo in SNGPF. Coupled with proper geochemical and reservoir evaluation, the developed expertise in handling amorphous silica enabled EDC not only to utilize two acidic wells in MGPF but also take advantage of their acidic discharges to prevent silica deposition in the brinelines (Alincastre and Nogara, 2001).

4. SOLIDS MITIGATING MEASURES

Continuous exploitation has shifted the discharges of the production wells of some EDC geothermal fields (Upper Mahiao, Tongonan-1, and South Sambaloran sectors in LGPF; Sandawa sector of MGPF and Balas-balas sector of SNGPF) from liquid-dominated to steam-dominated indicating the vertical and lateral expansions of the steam zone. This has translated to increased steam supply for power generation but some of the dry well discharges also contained significant total suspended solids (TSS) >5 mg/kg. The solids consist mainly of passivating corrosion products removed by the eroding actions of the formation materials that enter through the well's slotted liners. Without an in-situ waterflow to capture the suspended solids, erosion-corrosion phenomena were experienced in wellhead and surface facilities as described by Villa et al. (2005), Angcoy et al. (2005b) and Angcoy et al. (2008). To maximize the benefit of additional steam, EDC developed methods to mitigate the damaging effects of the suspended solids by scrubbing systems utilizing either hot separated brine or cold water (Figure 5). In areas with no water supply, a wellhead solids removal system was installed, designed to dislodge the solids by taking advantage of the steam discharge velocity and centrifugal force. The solids mitigating measures significantly reduced the TSS levels in the steam discharge by 80 to 100% while thinning rates in the surface facilities were reduced by 60 to 99% based on ultrasonic thickness gauge measurements. The increased amounts of solids flushed with the water phase were efficiently collected in modified solid traps to prevent reducing the capacity of injection wells (Villa et al., 2007; Sambrano and Nogara, 2008).

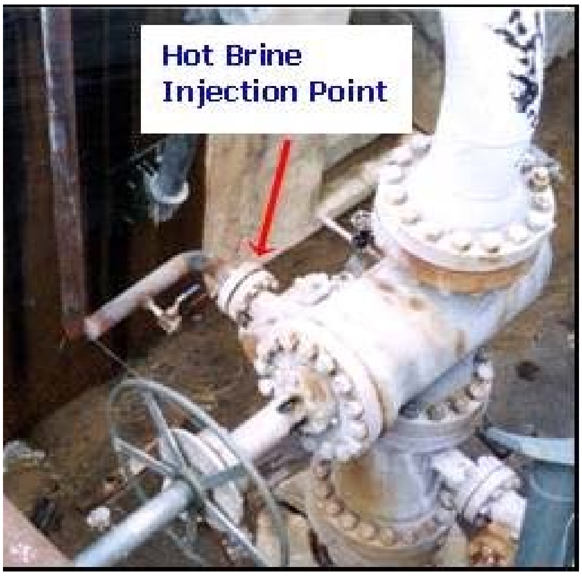

FIGURE 5: Hot brine wellhead washing

5. ON-LINE STEAM PURITY MONITORING

EDC's on-line steam purity monitoring (SPM) system was ingenuously developed in-house out of a responsibility to ensure that the power plants not only receive the required quantity but also the highest purity of steam supply (Figure 6). This technology was commissioned in 1983 and later perfected and operated as an on-line system in 1996. On-line SPM is based on the concept that isokinetically-sampled and condensed steam containing metal ion like sodium (Na) would generate a characteristic wavelength once burned in low temperature. The discrete wavelength can be isolated using optical filter and the amount of light emitted can be detected by a photodetector. The presence of sodium beyond the allowable limit indicates brine carryover, which is rich in scale-forming components like chloride, iron, and silica. It was also demonstrated that similar spikes in wavelengths are generated due to elevated levels of suspended solids in steam thus extending its application to early detection of solids phenomena widely experienced and posing problems in sectors with steam-dominated discharge (Section 4).

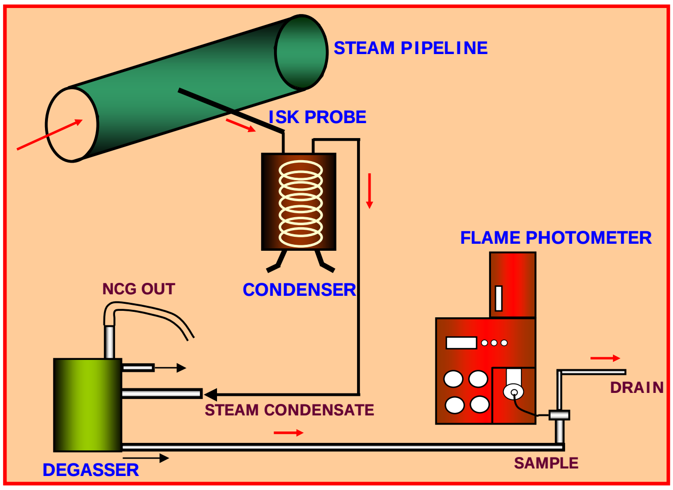

FIGURE 6: Schematic diagram of an on-line steam purity monitoring

The technology provides quick, reliable, and continuous data during normal plant operations (Figure 7), achieving greater control to variables that affect steam purity without additional burden to personnel and at the least cost to the company. For instance, total installation cost in all project sites of EDC saved an annual operating expense equivalent to USD 400,000-900,000 from manual sampling and analysis which are not capable of providing immediate results. Furthermore, real time data from SPM translated to additional company savings through minimal power plant shutdowns, reduced incidence of scaling, corrosion, and erosion in turbines and downstream facilities, and improvements in the design and operation of the steam gathering system like during separator vessel and scrubbing line efficiency tests.

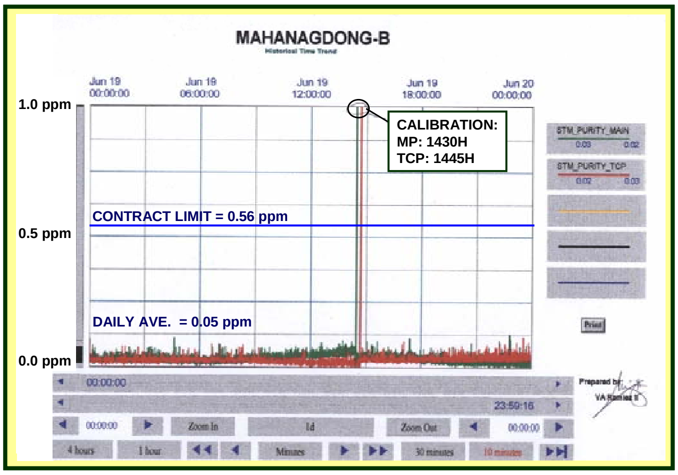

FIGURE 7: Real time data logged by on-line SPM

6. SUMMARY AND FUTURE OUTLOOK

The adopted practices and practical technologies developed through almost three decades of geothermal experience and expertise (tracer tests, scale inhibition, solids mitigating measures and on-line steam purity monitoring) are key factors in the integrated management of EDC's dynamic geothermal fields from the reservoir up to the surface facilities. Tactical development and maintenance of EDC's geothermal fields is reflected by the private sector's enthusiastic response to the company's privatization program in 2006 and 2007. In 2008, commissioning of the acid inhibition system in well MG-9D, Mahanagdong sector in LGPF will launch the full utilization of wells with acidic discharges. Successful acid neutralization technology will potentially generate an additional 19 MWe in Mahanagdong and 35 MWe in Alto Peak sectors in LGPF and facilitate utilization of acid wells in BGPF, MGPF, SNGPF, Mt. Labo and Mt. Cagua.

Under the leadership of a new management controlled by Red Vulcan Holdings Corp. (a consortium led by the country's largest vertically-integrated power generation firm FirstGen Corporation), EDC plans to widen its installed capacity base by putting up new power plants and bidding for state-owned geothermal assets. Expansion geothermal projects include building of new integrated steam and power-generating facilities with a total capacity of up to 310 MWe to support the growth in power demand foreseen by the government. The projected timetable of the projects are Nasulo in Negros (20 MWe) and Cotabato (50 MWe) projects by 2010; the projects in Albay and Sorsogon which include Tanawon (50 MWe) by 2011; Rangas (40 MWe) and Kayabon (40 MWe) projects and Dauin in Negros (40 MWe) by 2012; and the Southern Leyte project (50-80 MWe) by 2015. EDC also looks forward to expand international cooperation in geothermal services, consultancy and drilling projects. It has recently signed a sixth drilling contract with Papua New Guinea's Lihir Gold Ltd. for a one-year deal worth USD 16.11 million. EDC is upgrading its seven onshore drilling rigs and drilling equipment. It will acquire a new and state-of-the-art 1,500 hp drilling rig capable of drilling to a depth of 15,000 feet to prepare the company for future international drilling contracts.

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