Proceedings of 9th NZ Geothermal Workshop 1987

RE-INJECTION EXPERIENCE IN STEAMFIELDS BEING OPERATED BY THE PHILIPPINE NATIONAL OIL COMPANY

Nazario C. Vasquez

Vice-president and General Manager
Philippine National Oil Company
Energy Development Corporation

KEYNOTE ADDRESS

Thank you, it is a pleasure to be here and address you on our experience with reinjection in the Philippines. PNOC is currently operating two producing steamfields:

1. Tongonan I, 3 x 37.5MW, Leyte Island
   - 12 production wells, 4 re-injection wells, 1 condensate injection well.
   - commissioned June 1983.
   - load following, serves islands of Leyte and Samat.
   - peak load to date: 72MW

2. Palinpinon I, 3 x 37.5MW, Negros Island
   - 21 production wells, 10 re-injection wells, 1 condensate injection well.
   - commissioned July 1983.
   - load following serves Negros Island and to be connected to the Panay Island grid by end 1988.
   - peak load to date: 55MW.

In addition, we are developing:

1. Bacon-Mnnito I, 2 x 55MW, Luzon Island
   - 18 production wells, 5 re-injection wells, 1 condensate injection well.
   - to be commissioned 1991.

2. Palinpinon II, 2 x 37.5MW, Negros Island
   - 13 production wells, 5 re-injection wells, 1 condensate injection well.
   - to be commissioned 1992.

With our steam fields, as in most areas of geothermal development, environmental constraints require the re-injection of most of the steamfield liquid effluent. The alternative. is to dispose of the fluids to the river systems which, in The Philippines, are normally used for rice field irrigation. The intolerance of rice to Boron is our most severe constraint on effluent disposal to the rivers and maintaining the river water Boron concentration below our permissible maximum of 2ppm normally restricts the allowable effluent flow to river systems to less than 10% of the separated liquid generation at full station load. This constraint was recognised at an early stage and the re-injection and production sectors were identified before the start of development drilling.

All our developments to date feature rugged terrain. One of the few advantages of this is that proper selection of the surface location of the wells, separator stations and the power station permitted the use of gravity re-injection systems. With piezometric water levels some 300m below CHF in Tongonan and 500m below CHF in Palinpinon it was concluded that, for the good permeabilities encountered during drilling, pumping to increase well capacities was not required.

Reservoir temperatures at both Tongonan and Palinpinon range to beyond 310°C and it was clear during development that the separator pressures necessary to ensure the separated liquid remained undersaturated with respect to amorphous silica would be Substantially in excess of 1.0MPa(abs). For example, in the Sambaloran sector of Tongonan, because of increased silica Concentration due to two-phase conditions in many of the production wells, the required separator pressure to maintain undersaturated conditions is around 1.6MPa(abs). As the required power station steam header pressures were much less than this : 5.8 kg/cm²(abs) in Palinpinon and 6.2 kg/cm²(abs) in Tongonan, these high separator pressures were unattractive because of the consequential penalties of reduced flash, increased steam superheat and the need for higher pressure steam piping downstream of the separators where secondary steam scrubbing is carried out. Reinjection testing during field development provided confidence that gravity injection of silica solutions supersaturated with respect to amorphous silica is feasible provided fluid residence times in the piping on surface and downhole are minimized and the re-injection wells themselves are operated at, or near, maximum capacity. This has since been confirmed by operating experience. With amorphous silica saturation ratios of up to 1.5 no new re-injection wells have been required by either field in the four years of operation so far. Total re-injection capacity has not substantially changed in either field. While capacity decreases have been noted in some wells these have been largely compensated for by increases in capacity in other wells. The observed decreases appear to have been associated with silica scale debris, shed by the two-phase and re-injection pipelines during line start-ups and shut-downs, entering the wells and forming blockages in the slotted liner. Because of this, it was necessary to develop strainers and traps suitable for service with supersaturated amorphous silica solutions and install; them near the re-injection wellheads to prevent solids from entering the wells. To investigate this further, a workover was carried out in 1987 on the re-injection well PN-8RD in Palinpinon which had developed a blockage in the slotted liner and hod suffered a decline in injective capacity from 90 kg/s to 45 kg/s at about the ame time as the blockage was detected. A drilling rig was used to clean the well to near bottom of the liner and subsequent capacity testing has shown the well capacity to have increased to over 150 kg/s.

While silica deposition is taking place in the re-injection piping, only a small fraction of the silica present above saturation concentrations is precipitating out. To date, we have not been able to detect any change in silica concentration along the surface re-injection pipework. Nevertheless, after four years of re-injection under supersaturated conditions some of the surface pipework now requires cleaning because of declining line capacities. The horizontal and near-horizontal portions of the surface piping were found to be the most seriously affected. We began pipeline cleaning this year and have found no great difficulty in removing the silica with small drilling rigs fitted with swivel heads for horizontal drilling. We feel four years of pipeline operation before cleaning is not unsatisfactory and that it justifies our efforts to minimize fluid residence times in the re-injection system.

Tongonan and Palinpinon are similar in that both power stations comprise the bulk of the installed capacity of an island grid. Although there are diesel generating units installed on both grids, it is normal for the geothermal plants to supply the full load and to meet all the load fluctuations. Typical load curves are shown in Figure 1. A requirement for both steam gathering systems has been the minimization of steam wastage and remotely operable throttling valves have been installed in each field on the two-phase piping of selected production wells allowing the steamfield control room to adjust the steam supply to match power station demand. As the steam supply is varied this of course results in a corresponding variation in re-injection flow. Where possible, this variation is minimized by prioritizing high enthalpy production wells for peaking steam requirements. The injection wells in service are selectd so that some additional capacity is available for peak loads and any excess re-injection load is by-passed to a "thermal pond" via a dump valve remotely operable from the steamfield control room. In this way, the conflicting requirements of operating the re-injection wells at or near full capacity while varying the steam supply to match the demand of a load variable power stations have been accommodated. One consequence of the above was that the largest steam producers have tended to have been selected for installation of the throttling valves as these are usually of higher Enthalpy. Accordingly, these valves have perhaps the most rigorous conditions of service of any in our steamfields with pressure differentials across the valves regularly exceeding 40 kg/cm^2. The valve design was developed in the Philippines and we are obtaining very satisfactory performance.

Operating the re-injection wells near full capacity with gravity re-injection systems requires that, even with separator water level control valves, the pressure of the re-injection piping at the separator station be close to the separator pressure. This places additional importance on separator pressure control as a reversal of the pressure differential between the separator vessel and the re-injection system, for example during sudden power station load changes, can lead to separator flooding and large scale carry-over of liquid into the steam system. This is of concern as, even if short periods of two-phase supply to a turbine do not cause damage, scaling of turbine blades under these conditions occurs rapidly requiring premature turbine shut-down for blade cleaning. In addition, it is clear that the high water level alarm devices usually fitted to separators may not indicate a separator flooded condition for a flood resulting from a sudden decrease in separator pressure as conditions inside the separator water drum may not be single-phase liquid but instead two-phase. Accordingly, inorder to be confident of operating the re-injection wells near full capacity, close attention has been paid to ensuring adequate control of separator pressures to avoid flooding during an upset condition.

As reported before (Harper, 1985), we have interpreted observed increases in production well reservoir chloride measurements as evidence of the return to the production sector of re-injected fluids. We have found that by carefully monitoring the surface and downhole chemistry of production and re-injection fluids and relating changes seen to physical measurements of temperature and pressure, production well output data, tracer tests and the field model, it has been possible to assess, on a relative basis, the individual production and re-injection wells and prioritize them for service. In retrospect, our decision to forego extensive production and re-injection sector testing in favour of earlier power plant commissioning has been justified. No new wells have been drilled since the two power stations and steamfields were commissioned in 1983 and, as Table 1 shows, we have retained substantially the same injection and steam production capacity available before exploitation. We have found that the heavy emphasis placed on establishing a base-line pre-exploitation database and then closely monitoring the physical and chemical changes of the wells and their produced fluids has allowed us to interpret these changes and make informed decisions on well utilization to achieve the optimum well configurations. In short, we have re-affirmed the value and importance of comprehensive monitoring programs to steamfield operation.

	Steam Available (tonnes/hr)		Reinjection Cap. Available (kg/sec)	
	1983	1987	1983	1987
TONGONAN	1155	1189	310	255
PALINPINON	1172	1200	1142	1205

Table 1: Available Steam and Reinjection Capacity of Tongonan and Palinpinon

I will now describe the re-injection systems of Tongonan, Palinpinon and that planned for Bacon-Manito. Our strategy has been to re-inject around the periphery of the fields, preferably into identified outflows. Within the individual constraints posed by each field, the re-injection wells are designed for injection into the hottest part of the outflows, as distant as is feasible from the production sector and so as to provide maximum dispersion. When structures recognized as likely to provide rapid returns of injection fluids back to the production sector are identified, these are avoided,

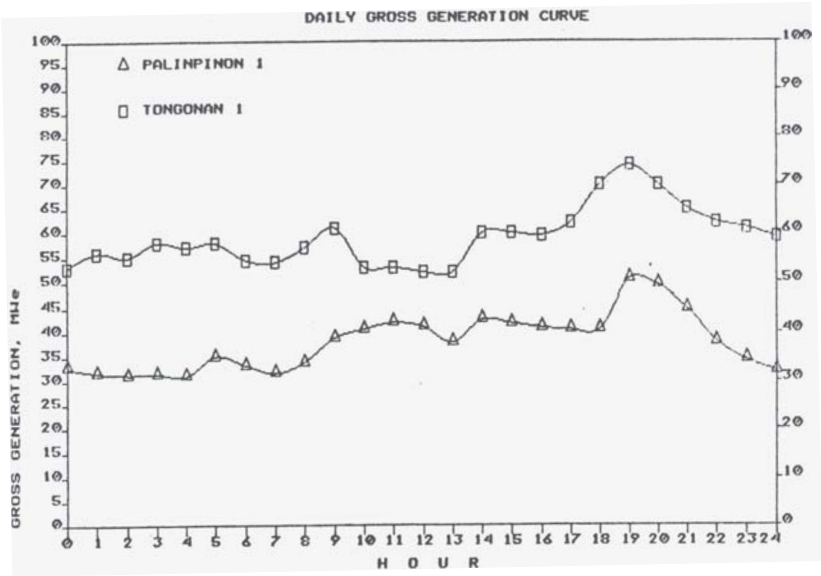

Figure 1: Representative Daily Load Curve for Tongonan and Palinpinon

1. TONGONAN

Tongonan I is the first stage development of a 552,5MW program for the resource. The balance of the development is dependent on the necessary increase in demand. Two 440 MW submarine cables connecting the islands of Luzon and Samar are now under consideration. The first 440 MW stage would carry the power from the development of the balance of the Tongonan resource, the second would require development of other geothermal resources in Leyte. Figures 2a & 2b shows the development plan and how it relates to the first stage Tongonan I development. We plan to continue to use gravity injection and to inject supersaturated silica solutions from separator stations serving high temperature resource areas.

The re-injection wells for Tongonan I serve two separator stations and are arranged so that two wells are dedicated to each station. Because of elevation differences, the Mahiao re-injection wells can also serve the Sambaloran but not vice-versa. A remotely operated isolation valve controls the flow of Sambaloran re-injection fluid to the Mahiao and a second remotely operated valve is used to control the flow of re-injected fluid to the thermal pond for controlled diqposal to the Mahiao river. Both valve controllers are installed in the steamfield control room for immediate operation whenever re-injection system pressures rise above critical values. Normal operation calls for wells 1R3D, 1R5D and 2R4D to be in service with well 2R3D held in reserve against maintenance requirements. Total fluid injected to date is approximately 26.70 million tonnes.

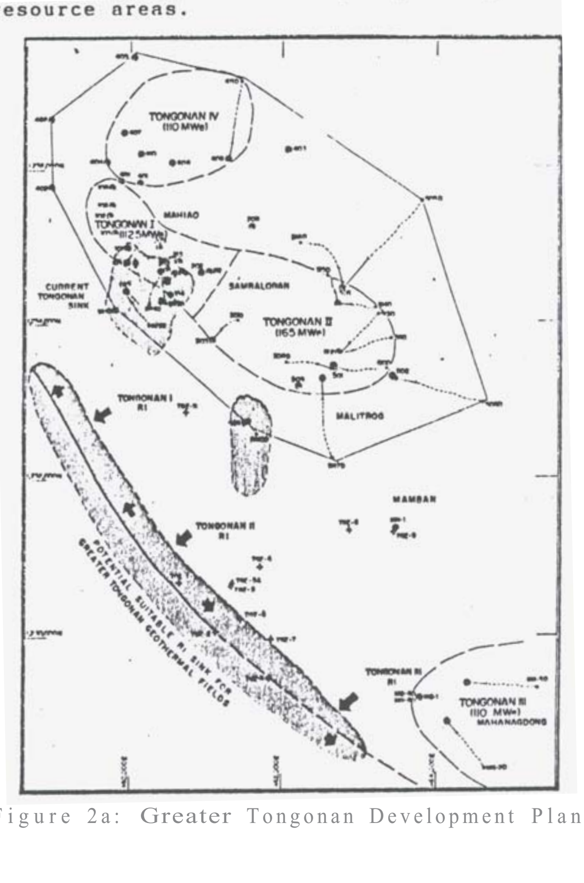

Figure 2a: Greater Tongonan Development Plan

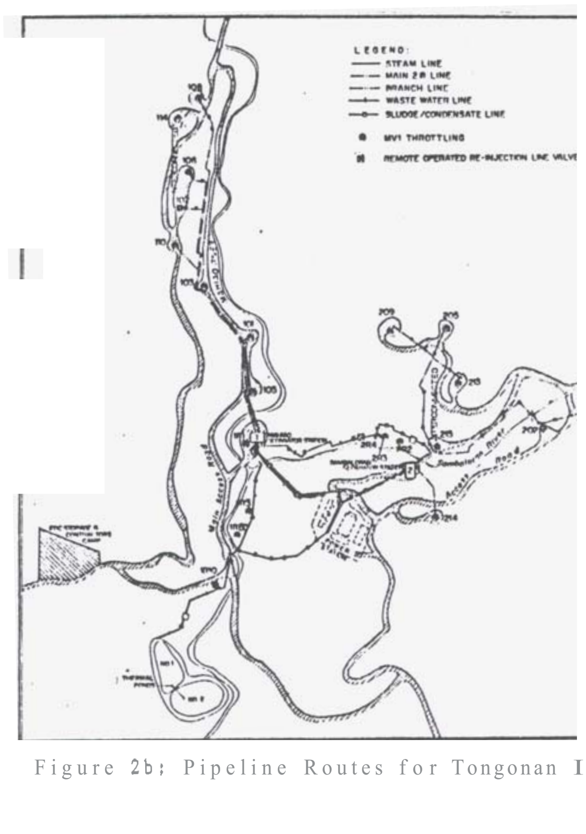

Figure 2b: Pipeline Routes for Tongonan I

2. PALINPINON

Palinpinon I is the first stage of a 225MW development program for the resource. Palinpinon II (2 x 37.5 MW) is programmed for commissioning in 1992 to meet the additional load of Panay Island which is to be connected to the Negros Island grid via a submarine cable now under construction. It is possible that the economic recovery will result in this second stage development being expanded to 3 x 37.5 MW. Figure 3 shows the development plan and how it relates to the existing Palinpinon I development. Again, we plan to use gravity re-injection but with the lower temperatures encountered in the Nasuji and Sogongon sectors, it is likely most of the re-injected fluids will be at or below saturation with respect to amorphous silica.

Palinpinon I has a single centralized separator station with the 10 injection wellheads located on three pads to the North-East. At current loads (peaking 55 MW) the average re-injection flow is around 65% of full load at 325 kg/s. Normal practice is to have five (PN-2RD, PN-3RD, PN-4RD, PN-5RD and PN-8RD) of the ten wells in service. These were carefully selected so as to minimize re-injection returns to the production sector. Further load increases will be met by distributing the flow over the balance' of the wells or by connecting new wells as required. Total fluid injected to date is approximately 78.4 million tonnes.

3. BACON-MANIT0

Bacon-Manito I (2 x 55 MW) is scheduled for commissioning 1991. We are currently drilling exploration wells to the East of the current development and hope to be able to commit to an additional 110 MW of development by the end of 1988.

Figure 4 illustrates the planned development of Bacon-Manit0 I. The steam gathering system will be split into two allowing dedication of one half to the supply of a single machine while maintaining the other during turbine-alternator maintenance shut-downs. There are two re-injection well pads: RB/RC and RA. It was originally intended to site all the re-injection wells on RB/RC but poor encountered permeabilities forced the inclusion of pad RA. Though wells drilled from pad RA have high (in excess of 100 kg/s) injection capacities the reinjection pipeline contains a siphon (see Figure 5). Pumping of the re-injection fluid was considered but analysis showed that the installation and operating costs made this less attractive than gravity injection. A consequence of the siphon is that pressure regulatory valves are required to avoid depressurization and consequential flashing in the up-comer. The long re-injection pipelines (over 3 km) and the associated high fluid residence times will require the re-injection system to be operated undersaturated with respect to amorphous silica. This will require the separators to be operated at 1.0 MPa (abs) or above.

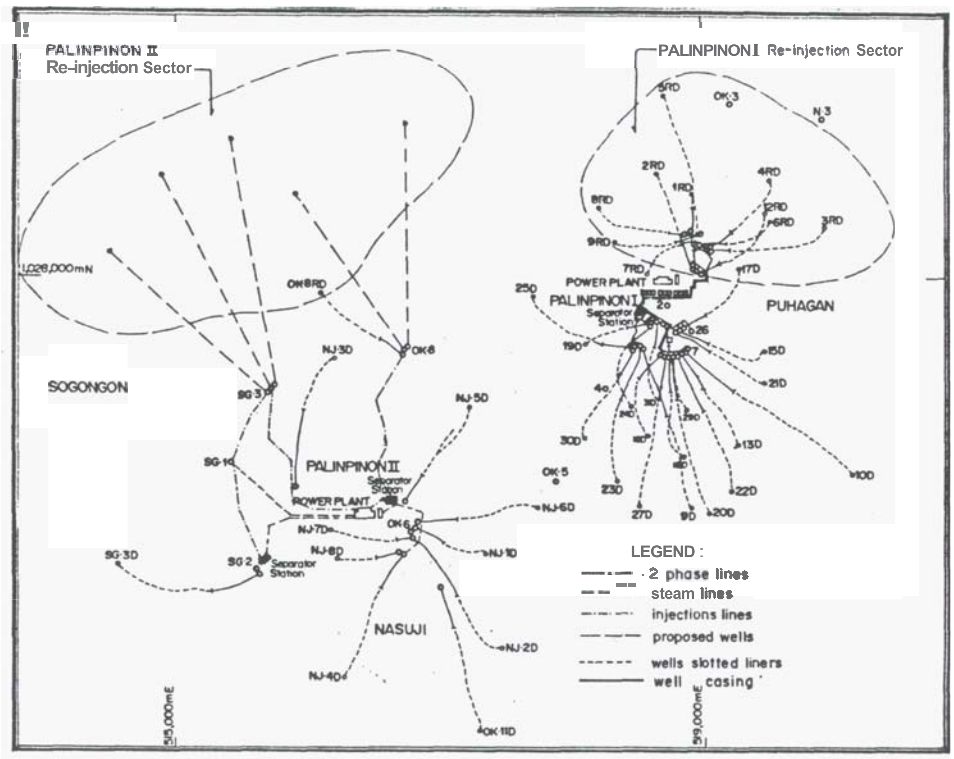

Figure 3: Greater Palinpinon Development Plan

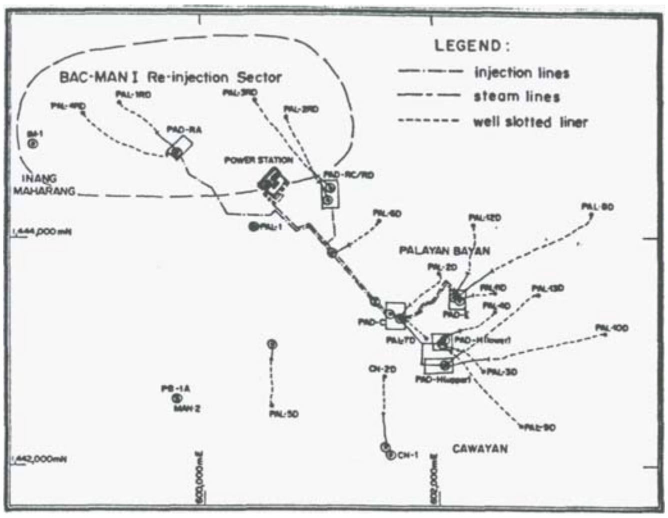

Figure 4: Bacon-Manito Development Plan

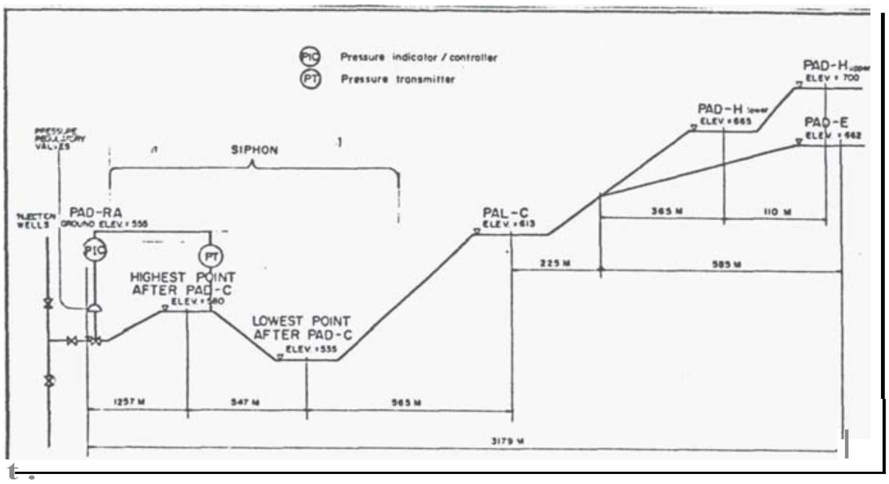

Figure 5: Schematic of Proposed BACMAN Reinjection Line

CONCLUSION

Four years of successful operation Palinpinon I and Tongonan I have demonstrated that gravity injection of fluids supersaturated with respect to amorphous silica is viable even under the special constraints imposed by supplying load following power plants. The operation of the re-injection system is vital to the operation of these and any future plants and is intimately linked to the operation of the production sectors. The importance of establishing baseline pre-exploitation well and reservoir data and, after the start of commercial operation, maintaining a comprehensive field monitoring program upon which to base operational decisions has been reaffirmed. We have a substantial development program in the Philippines and, now, in our fifth year of operation of Tongonan I and Palinpinon I, we are looking forward to the future with confidence and hope to be able to share our experience with other countries in developing their geothermal resources.

REFERENCES

Malixi, P.V. (1982): The Anatomy of Growth of Philippine Geothermal Development. Proceedings of Pacific Geothermal Conference.

Maunder, B.R., Brodie, A.J., Tolentino, B.S., (1982): The Palinpinon Geothermal Resource, Negros, Republic of the Philippines - An Exploration Case History. Proceedings of Pacific Geothermal Conference.

Harper, R.T., Jordan, O.T., (1985): Geochemical Changes in Response to Production and Re-injection for Palinpinon I Geothermal Field, Negros Oriental, Philippines. Proceedings of the 7th New Zealand Geothermal Workshop.

Lovelock, B.G., Cope, D.M., Baltazar, A.J., (1982): A Hudrogeochemical Model of the Tongonan Geothermal Field. Proceedings of Pacific Geothermal Conference, Auckland, New Zealand.