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Improved Efficiency of Solid Trap Installed in Brine Injection Pipeline of Leyte Geothermal Production Field, Philippines

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ABSTRACT

The original 20" single pipeline solid traps installed in Tongonan-1 and in most geothermal fields of Energy Development Corporation (EDC) are ineffective in capturing minute solids carried by the brine, resulting to capacity decline in injection wellbores. Installation of a modified and enlarged solid trap at well 1R8D consisting of 36" parallel pipeline was completed on t January 2003. The minute solids that go with the brine are removed by significantly reducing the fluid velocity in the modified solid trap allowing the solids to settle in the solid trap prior to brine injection into the well. When it was opened and evaluated in June 2003 after 167 days of utilization, the solids collected at the modified solid trap were composed of polymerized silica (50%), corrosion products (40%) consisting of magnetite and hematite, and formation materials (10%). The total weight of solids collected was 3,445 kg for an estimated deposition rate of 21 kg/day. Iron catalyzed or enhanced polymerization of silica also likely occurred in the brine enriched with magnetite, which induced polymeric silica formation as evidenced from the debris collected. Removing the bulk of the solids from the brine before it is injected significantly reduces the potential of enhanced silica polymerization and minimizes the rapid decline in injection capacity of the well. The documentation and evaluation showed that the modified solid trap installed had an improved performance in capturing the minute solids suspended in the brine compared to the old design. Similar observation was noted when a solid trap of similar design was installed in other injection wells which showed an improved efficiency. This paper demonstrates that even a very simple technology can be very useful is solving some complicated problems in geothermal operations.

1. BACKGROUND

Steam washing started at the Tongonan-1 sector of the Leyte Geothermal Production Field on March 2001. It was implemented at the 3 main two-phase lines of its Mahiao Separator Station-1 (SS#1) to: (1) capture solids that go with the steam discharged from the well, and (2) minimize the erosion that occurred at the separator vessels. The separated brine including the wash fluid enriched with solids removed from the steam was initially disposed and injected to well 1R3 (Fig. 1). Well 1R3 was initially accepting 54 kg/s of brine on March 2001. After four months of utilization, brine dumping from the separator to the silencer and then to the thermal pond became necessary because of the abrupt decline in the capacity of the injection well by as much as 50% (~26 kg/s). It required the disposal of dumped brine to the thermal pond and pumping to well 1R10. This scheme was not sustainable for long term operation due to the limit in capacity of the thermal pond. When 1R3 was isolated for inspection, the original solid trap installed was able to collect only a small amount of solids. But when it was vertically discharged in October 23, 2001, significant volume of tiny particles of solids were ejected (Fig. 2). indicating that the solids were not captured by the original solid trap and were deposited inside the well bore that eventually blocked the well and dropped its injection capacity (Villa, 2002).

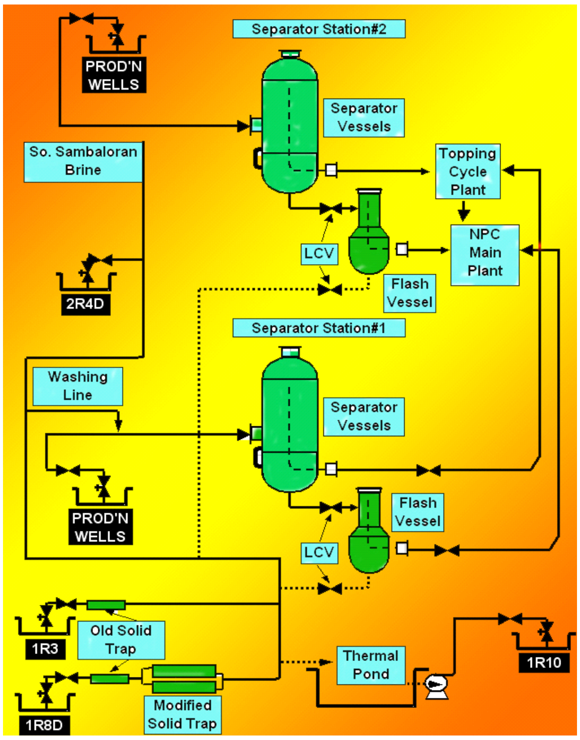

Figure 1: Schematic diagram of Tongonan-1 brine disposal.

Well 1R8D was worked-over on December 2000 intended to replace 1R3. Based on completion test data, its capacity was at 180 kg/s. After cut-in, it was used solely to accommodate all the separated brine from SS#1 (including the wash fluid with solids), the brine from SS#2 and the brine diverted from South Sambaloran after 1R3 was cut out (Fig. 1). The steam washing rate of the main two-phase lines 1, 2 and 3 of SS#1 were also increased to scrub further the solids that go with the steam and minimize the erosion rate in the vessels. At relatively the same injection load until May 2002, it was noted that the wellhead pressure of 1R8D increased, suggesting that the well was tightening. There was a growing concern that this may lead again to an abrupt decline in capacity of 1R8D similar to what happened to 1R3, especially that more solids were further removed with the increase in washing rate. It was then decided to redesign and enlarge the solid trap and install two units in parallel at 1R8D branch line.

Figure 2: Well 1R3D clearing discharge showing some dark debris being ejected.

Also, while steam washing is in service, there were several instances that the level control valves (LCV) of the separators and that of the Flash Vessel (FV-100) downstream of the main separators got stuck due to some debris that frequently lodged at the valve seats of the LCVs (Fig. 1). This suggests that a significant amount of solids was washed by the brine and carried towards 1R8D, portions of which were left at the LCV when opened. During the Preventive Maintenance Servicing (PMS), some solids were also noted to have deposited at the brine drum of the flash vessel. It was then expected that in due time these captured solids would build up and totally block the well bore

2. DESIGN CONSIDERATIONS

The original solid trap installed in 1R8D is a single, 20-inch diameter pipe around 6 meters in length (Fig. 3). Due to minute size of the solids captured by the brine and the high velocity and turbulent nature of the brine (Reynold's number = >4,500) flowing along the brine line, this solid trap was ineffective because when it was opened, only a small amount of solids were collected. This was contrary to the observation upstream in the separator and flash vessels, that significant amount of solids were deposited.

The characteristic of the solids captured by the wash fluid is that it has a sandy texture and with a particulate size that tends to be lighter and remains suspended in the brine if the velocity is high enough to carry it. But if the velocity is significantly reduced and the flow is laminar, these solids will have enough time to settle. This was noted from the solids deposition mechanism at the bottom of the FV-100 brine drum. The modified solid trap was designed to significantly reduce the brine velocity. It allowed sufficient time for the captured solids to settle down before the brine exits the solid trap and injected into the well. It consists of two 36-inch pipe by 7.5 meters in length installed parallel to each other (Figs. 4). The velocity of the brine inside the solid trap is significantly reduced due to the increase in the diameter of the pipe from 10 inches to 36 inches aided further by dividing the total flow into two lines. Furthermore, double-baffle plates were installed inside the solid trap to serve two purposes: (1) to reduce further the velocity of both brine and solids inside the large-diameter pipe (Reynold's number = ~1200); and (2) deflect the settling solids at the bottom of the slow moving brine, allowing only the cleaner upper portion layer to overflow to the next chamber. The outlet of the solid trap was located near the top to allow the solids carried to the second chamber to settle further and allow the upper layer brine that is relatively free of solids to pass through.

Figure 3: The original 1R8D solid trap installed.

Figure 4: The new 1R8D modified solid trap installed.

3. 1R8D INJECTION LOAD MONITORING

Presented in Table 1 is the injection load of 1R8D with its corresponding wellhead pressure between December 20, 2001 and November 11, 2002. These were the measurements before the modified solid trap was installed along the line on January 15, 2003. Succeeding measurements after the modified solid trap was installed are included in the latter part of the table.

As shown in Table 1, well 1R8D showed initially an increasing wellhead pressure (WHP) at almost constant brine flow until May 2002, interpreted to be tightening of the well bore. However, when South Sambaloran and SS#2 increased its diverted brine flow (Fig. 1), W1R8D increased its brine load. The well still accepted up to 190 kg/s. The reduction in load in September 2002 was when steam washing was cut out to evaluate its effect on steam condensation. The succeeding load measurements after the modified solid trap was installed showed no reduction in capacity or tightening of the well. Also, its WHP decline corresponds to the decline in brine loading, indicating that the well is not tightening.

Table 1: Loading of reinjection well 1R8D.

Date	WHP, MPag	Load, kg/s	Remarks
20-Dec-01	0.38	70.5	Load
16-Jan-02	0.51	166.3	Load, including brine diversion
27-Mar-02	0.57	163.5	Load
2-May-02	0.58	169.7	Load
13-Jun-02	0.55	184.3	Capacity, including. So. Sambaloran and SS#2 brine flow
7-Aug-02	0.55	179.8	Load
20-Aug-02	0.5	182.6	Capacity
24-Sep-02	0.45	98.1	Load
11-Nov-02	0.61	191	Steam washing cut out test
**Modified Solid Trap Installed*			
16-Jan-03	0.48	182	Capacity
25-Jan-03	0.32	65.1	Load shared with 2R4D
6-Feb-03	0.4	98.5	Load shared with 2R4D
27-Feb-03	0.39	89.7	Load shared with 2R4D

4. 1R8D MODIFIED SOLID TRAP INSPECTION

To determine its efficiency, it was decided to visually inspect the internals of the modified solid trap. It was opened and inspected on July 2-3, 2003. Both ends of the two parallel 36-inch solid traps were opened. Upon inspection, there was no observed deposition at the main brine line (Fig. 6). However, there was a significant amount of deposits inside the modified solid trap. It was noted that significant amount of solids were collected inside the solid trap near the end section (Figs. 7 to 8). The total weight of the debris collected was 3,445 kg, for an estimated deposition rate of 20.6 kg/day (Villa, 2002).

Figure 6: Minimal debris collected at the main brine line even after the installation of the new modified solid trap.

Samples of solids were taken from inside the well 1R8D modified solid trap and were sent for petrologic analysis. Presented in Table 2 are the results of the megascopic/petrologic analyses of the samples. The analysis of the collected debris samples showed that these are composed of polymerized silica (50%), corrosion products (40%) consisting of magnetite and hematite, and formation materials (10%).The corrosion products are those that were removed from the 2-phase line and separator vessels after washing with brine at the main two-phase line while the formation materials directly came from the wellbore which initiated the erosion along the main 2-phase line. Some of the collected silica was probably old deposits from the 2-phase lines that was eroded and carried over all the way to the separator station. While the other amorphous silica are formed by enhanced silica polymerization reaction. These solids were flushed out from the separator and flowed through the brine line and finally disposed to the injection well. With the installation of the modified solid trap, these solids were captured before the brine is injected into the wellbore.

Figure 7: Photos inside the modified solid trap inlet and outlet during first inspection.

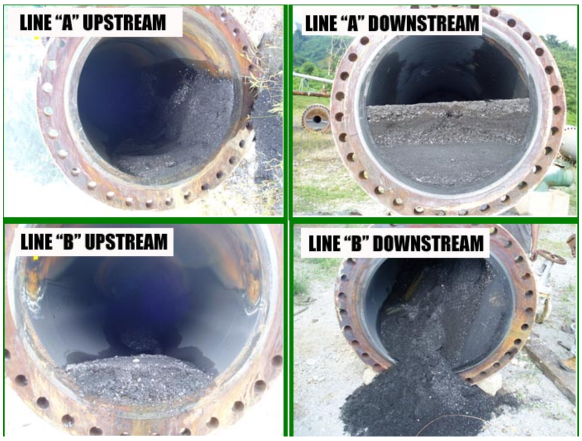

Figure 8: Photos inside the modified solid trap inlet and outlet during the succeeding inspection.

Table 2: Megascopic and Petro analysis of debris collected from the solid trap.

Source	Analysis
1R8D modified solid trap	Black conglomerate sample (consisting of small sub-rounded chips loosely cemented) composed of: 50% - amorphous silica 20% - magnetite 20% - hematite 10% - impurities (rocks/formation materials)

4. MODIFIED SOLID TRAP EFFICIENCY EVALUATION

Well 1R8D modified solid trap was almost totally filled near the top of the baffle plates when opened (Fig. 8). In fact, it is suspected that some of the solids were partly carried over by the brine into the wellbore based on the profile of the solids that was deposited. Deposition was significant since the utilization of the solid trap until it was opened is 167 days from commissioning. With the 3,445 kg of solids collected, it translated to 20.6 kg/day of debris retained in the solid trap. If this amount was not removed from the brine, it is likely that the capacity of well 1R8D would have eventually declined much earlier. These solids will fill the wellbore permeable zones similar to 1R3 and eventually drop the capacity of the well to accept the injected brine.

The amorphous silica in the collected debris (50% of the total volume collected) is mainly made up of old silica deposits eroded from the main 2-phase lines, branchlines and brinelines that is evident from solid silica flakes observed from the bulk of the samples. The other source is probably the catalyzed polymeric silica formation. The silica saturation index (SSI) of the brine injected to 1R8D is within the saturation limit. At this level, silica deposition is considered minimal and tolerable based on historical data and deposition characteristics of Tongonan brine. However, the polymerization of silica could be catalyzed by the presence of ferric iron (Fe^{+3}). According to R.K. Iler (1979), a very small spherical silica particle would yield a large polymerized particle in the presence of Fe ions. The iron would combine with the SiOH group and in the process also attach to the other SiOH groups; thus, promoting the bonding with more SiOH molecules that eventually make the size of the particle larger. This polymerization process is shown by the reaction described by this equation:

$$(\text{-SiOH})m + Fe^{3} = (\text{-SiOH})nFe^{3-n} + nH+, Qn \qquad (1)$$

The megascopic and petro analysis of the solids that were collected at the solid trap showed that it was 20% composed of magnetite (Fe_3O_4) and 20% hematite (Fe_2O_3). Magnetite is in the form of Fe^{+3} and hematite is Fe^{+2} in free ionic form if it dissociates. Moreover, the brine injected to 1R8D is in itself enriched with total Fe in solution since the chemical analyses revealed an elevated total Fe ion level of 0.5 to 6.0 ppm. The source of this elevated Fe level could be the continued erosion of the pipe wall of the wellbores, branchlines and 2-phase lines caused by the formation materials that go with the steam discharge of the production wells with dry steam discharge. Some of the free Fe ions in the brine could be in the form of Fe^{+3} that most probably caused this enhanced polymerization of silica. Thus, if it would be given enough time to react with the silica in the brine, it would eventually promote the formation of globules of polymerized silica as explained by equation 1. By allowing the polymerization to occur at the solid trap instead of at the wellbore, it prevents the bulk of the polymerized silica from reaching the wellbore and allowed it to be captured upstream. This will also remove the ferric iron in the solution before it will be injected to the well, thus, mitigating silica deposition at the wellbore that probably contributed to the blockage in 1R3 and 1R8D. This is where the 1R8D modified solid trap become more beneficial. Thus, the same design of solid trap was installed in well 1R9D after it was drilled and commissioned as a back-up well for well 1R8D.

However, based on observation during inspection there is a limit in the capacity of the modified solid trap to capture the solids. Its efficiency to trap the solids would be reduced when the solids start to build up and begin filling the chambers near the baffle plates at the end section of the solid trap. It is, thus, proper to prevent the captured solids from accumulating inside the solid trap through regular draining of the drains installed near the baffle plates (Fig. 9). Also, a bi-annual inspection and cleaning should be conducted.

The subsequent utilization period and documentation of the solids after cleaning the solid traps installed at wells 1R8D and 1R9D modified solid traps are tabulated in Table 3. The result showed that the debris collection rate is not constant. It ranges from 8 to 61 kg/day at 1R8D while at 1R9D ranges from 0.45 to 24 kg/day (Villa, 2006). The wide range in the debris collection rate is caused by several factors among which are: (1) the amount of solids discharged from the production wellbore may not be constant and (2) the loading of the injection wells are not constant. But the result clearly showed that even when the loading and amount of solids present in the brine vary, the solid trap remained effective as long as its deposition chamber is not filled-up.

Figure 9: Debris discharged from the Modified Solid Trap drain box.

Table 3: Debris collected by the modified solid trap at wells 1R8D and 1R9D with time.

WELL	UTILIZATION DATES	NO. OF MONTHS	DEBRIS COLLECTED
1R8D	January to July 2003	6	3,507 kgs. (21 kg/day)
	July 2003 - November 2004	16.5	4,610 kgs. (9 kg/day, excluding carry-over)
	November 2004 - April 2005	5	1,215 kgs. (kg/day)
	April 2005 - July 2005	3	5,415 kgs. (61 kg/day, excluding carry-over)
	October 2005 - February 2006	4	200 kgs. (1.6 kg/day)
	February 2006 - August 2006	6	1,764 kgs. (11 kg/day)
1R9D	March 2005 - October 2005	6.9	1,620 kgs. (9 kg/day)
	October 2005 - February 2005	3.7	50 kgs. (1.6 kg/day)
	February 2006 - August 2006	6.1	4,410 kgs. (24 kg/day)
	August 2006 - December 2006	4.3	1,980 kgs. (15 kg/day)

5. SUMMARY AND CONCLUSIONS

The old solid trap (20" x 6 meters) configuration originally installed in injection wells was ineffective in capturing the solids that are washed from the steam. The inspection of the main brine line showed that the debris did not settle along the line nor in the original solid trap as the minute solids were easily carried over by the brine down the well bore. The carried over solids have accumulated in the permeable zones of the well thus showing a drop in well capacity. The observed capacity decline in well 1R3 and initial tightening of well 1R8D were attributed to the accumulation of the solids at the well bore when it was not captured by the old solid trap. The solids that go with the brine can be removed only by significantly reducing the velocity (Reynold's number reduced from 4500 to 1200) of the brine allowing it to settle first before injecting the brine into the well.

The solids collected at the modified solid trap are composed of polymerized silica (50%) and corrosion products (40%) composed of magnetite and hematite while the rest of the solids were made up of formation materials. The corrosion products are similar to those washed upstream of the separator vessels. The total weight of solids collected from the modified solid trap ranges from 0.45 to 61 kg/day depending on the amount of solid present in the brine and the loading of the injection well. Catalyzed or enhanced polymerization of silica most likely occurred since the brine is enriched with free Fe ions in solution. Removing the bulk of the solids from the solution before being injected significantly reduced its potential to deposit. Indeed, the modified solid trap served its purpose of removing the minute solids carried by the brine as shown by the improved performance of wells 1R8D and 1R9D in lengthening its utilization time and minimized the rapid decline in injection capacity of these wells. The very simple design concept of the modified solid trap demonstrates that even a very simple technology can be very useful is solving some complicated problems in geothermal operations.

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