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

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Keywords

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ABSTRACT

The existing 20" single pipeline solid traps installed in Tongonan and in most geothermal fields in the Philippines 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 consisting of 36" parallel pipeline was completed last January 2003. The minute solids that go with the brine are removed by significantly reducing the velocity in the enlarged solid trap allowing the solids to settle first in the solid trap. 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 kgs. for an estimated deposition rate of 21 kgs/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. This will become a major factor in the decline in injection capacity. Removing the bulk of the solids from the brine before it is injected would greatly reduce its potential to polymerize and minimize the decline in the injection capacity of the well. The documentation and evaluation showed that the modified solid trap was successful in attaining its objective.

Background

Steam washing started at the Tongonan-1 sector of the Leyte Geothermal Production Field, Philippines on March 2001. The steam washing was implemented at the main two-phase lines of its Mahiao Separator Station-1 (SS#1) to (1) capture the solids that go with the steam discharged from the well and (2) to minimize the severe erosion that occurred at the separator vessels. The separated brine including the wash fluid enriched with solids removed from the steam was injected to well 1R3D (Figure 1). Well 1R3D was initially accepting 54 kg/s of brine on March 2001. After four months of utilization, brine dumping from the separator to a silencer and then to a thermal pond became necessary because of the abrupt decline in the capacity of the injection well by as much as 50%, or 26 kg/s. This also necessitated the reduction in wash fluid rate designed to control

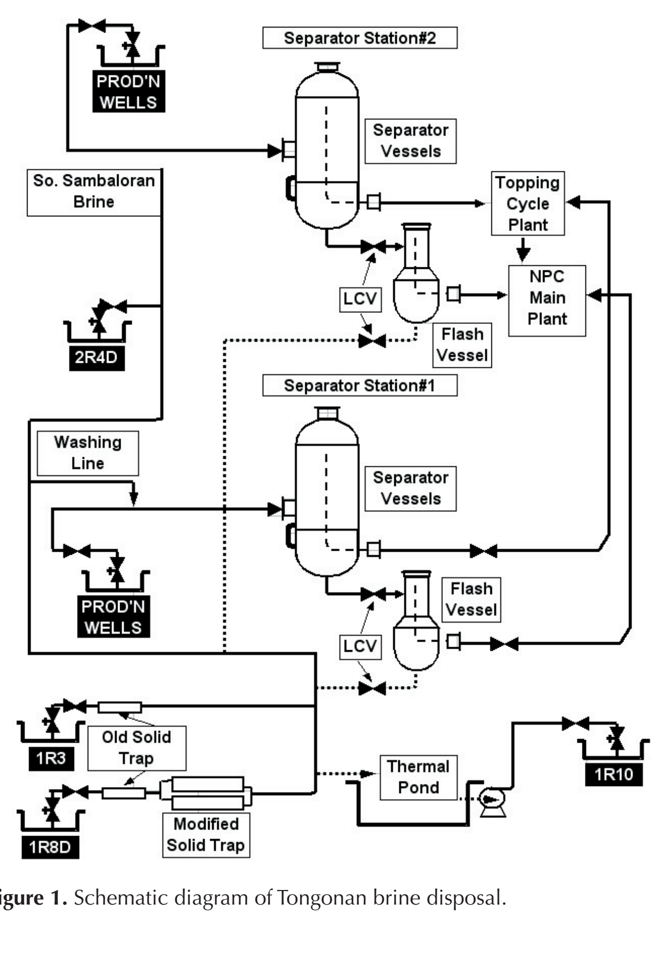

Figure 1. Schematic diagram of Tongonan brine disposal.

the erosion at the vessels. It also necessitated the disposal of excess brine to the thermal pond and pumping it to well 1R10. This scheme was not sustainable for long term operation due to the limit in capacity of the thermal pond. When 1R3D was isolated for inspection, the solid trap was able to collect only a small amount of solids. But when it was vertically discharged in October 23, 2001, significant tiny particles of solids were ejected indicating that solids not captured by the solid trap were deposited inside the well bore that blocked the well and significantly dropped the injection capacity.

Well 1R8D was worked-over on December 2000. However, it was only connected to the T1PF main injection line on December 2001 after the new pipe bridge and line repair were completed. Based on completion test data, its capacity was at 180 kg/s. It was then 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 (Figure 1). The steam washing rate of the main 2-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 due to the increase in washing rate. It was then decided to redesign and enlarged the solid trap and install two units in parallel at 1R8D branchline.

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 stucked due to some debris that frequently lodged at the valve seats of the LCVs. This suggests that significant amount of solids were washed by the brine and carried towards 1R8D, portion of which were left at the LCV (Figure 1). During 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 wellbore.

Figure 2. The original 1R8D solid trap.

Design Consideration

The original solid trap installed in 1R8D is a single 20-inch diameter pipe around 6 m in length (Figure 2). Due to minute size of the solids captured by the brine and the high velocity (Reynold's number = 4500) of the brine flowing along the brine line, this solid trap was proven 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 removed by washing the steam with brine.

The characteristic of the solids captured by the wash fluid is that it has a minute sandy texture and 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, then the solids will have enough time to settle down. This was noted from the solids deposition mechanism at the bottom of the LCV valve seats and at FV-100 brine drum. The modified solid trap was designed to significantly reduce the brine velocity. It allowed and gave 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 Class G 36-inch pipe by 7.5 m length installed parallel to each other (Figure 3-4). From the main reinjection line, the flow in the

Figure 3. The new modified solid trap at 1R8D.

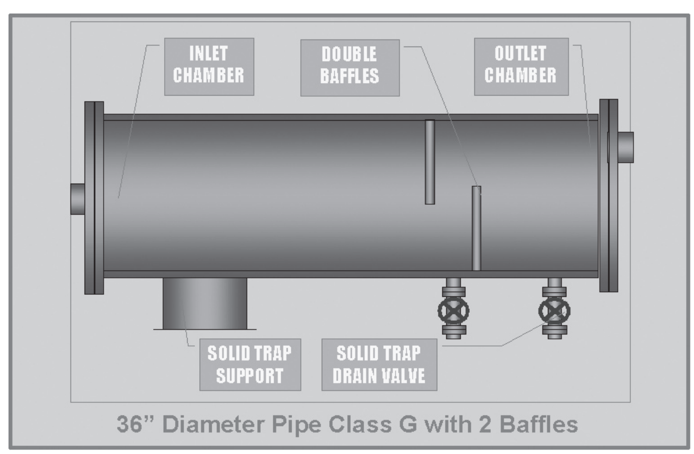

Figure 4. 1R8D modified solid trap design.

10-inch brineline is divided by a bifurcator before it enters the two solid traps. To recover the original velocity of the brine, the exiting brine flows (after most of the solids have been removed) were joined again by another bifurcator, then injected to 1R8D. The velocity of the brine inside the solid trap is significantly reduced due to the increase in the diameter of the pipe from 10-inch to 36-inch and since the total flow has been bifurcated into two. Furthermore, double baffle plates were installed inside the solid trap (Figure 4) 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.

W1R8D Injection Load Monitoring

Presented in Table 1 is the reinjection load of 1R8D with its corresponding wellhead pressure between December 20, 2001 to November 14, 2002. These were the measurements before the modified solid trap was installed along the line last January 15, 2003. Succeeding measurements after the modified solid trap was installed are included in the latter part of the table.

Table 1. Injection load trend of Well 1R8D.

Date	WHP, MPag	Load, kg/s	Remarks
12/20/01	0.38	70.5	Load
01/16/02	0.51	166.3	Load, inc. brine diversion
03/27/02	0.57	163.5	Load
5/2/02	0.58	169.7	Load
6/13/02	0.55	184.3	Cap., inc. So. Sambaloran and SS#2 brine flow
8/07/02	0.55	179.8	Load
8/20/02	0.50	182.6	Capacity
9/05/02	0.42	172.3	Steam washing cut-out test
9/05/02	0.40	155.8	Steam washing cut-out test
9/24/02	0.45	98.1	Load
11/11/02	0.61	191.0	Steam washing cut-out test
11/14/02	0.48	177.4	Steam washing cut-out test
Modified Solid Trap Installed			
1/16/03	0.48	182.0	Capacity
1/25/03	0.32	65.1	Load shared with 2R4D
2/6/03	0.40	98.5	Load shared with 2R4D
2/27/03	0.39	89.7	Load shared with 2R4D

Initially, W1R8D showed an increasing 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, W1R8D increased its brine load. The well still accepted up to 190 kg/s. The reduction in load was during the time when steam washing was cut-out to evaluate its effect on steam condensation while steam washing was conducted. Succeeding load measurements after the modified solid trap was installed showed no reduction in capacity or tightening of the well. Also, W1R8D load was distributed to 2R4D, its WHP declined corresponding to a decline in brine loading, indicating that the well is not tight.

1R8D Modified Solid Trap Inspection

To determine its efficiency it was decided to visually inspect the internals of the modified solid trap. The modified solid trap was opened and inspected on July 2-3, 2003. Both ends of the two parallel 36-inch solid traps were opened. Upon inspection, it was observed that significant amount of solids were collected inside the solid trap near the end section (Figure 5 to 12). While there was no observed deposition at the main brineline (Figure 13), there was a significant deposition inside the modified solid trap. The profile of the formation of debris inside the solid trap is shown in Figure 5. A total of 64 half-bags of sandy like deposits were collected from the solid trap. The total weight of the collected debris was 3,445 kgs, for an estimated deposition rate of 20.6 kg/day.

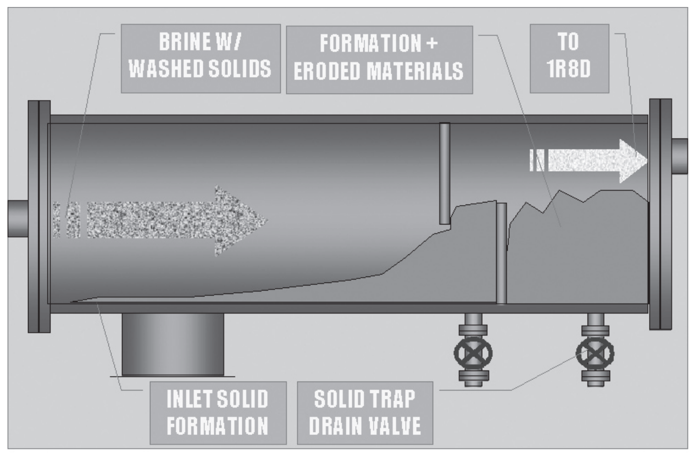

Figure 5. Profile of debris inside the solid trap.

The samples of solids taken from inside the 1R8D modified solid trap was sent to Petrolab for Petrologic analysis. Presented in Table 2 are the results of the megascopic and petrologic analyses of the samples. Note that from the analysis of the samples, it is shown that these are composed of polymerized silica (50%), corrosion products (40%) consisting of magnetite and hematite, and formation materials (10%). These corrosion products are those that were removed from the steam after washing it with brine at the main two-phase line. These solids were flushed out from the separator and flowed through the brineline.

Table 2. Megascopic analysis of 1R8D samples.

Source	Analysis
1R8D modified solid trap	Black conglomerate sample (consisting of small subrounded chips loosely cemented together) composed of: 50% - amorphous silica 20% - magnetite 20% - hematite 10% - impurities (rocks/formation matl's.)

Figure 6. 1R8D modified solid trap inlet.

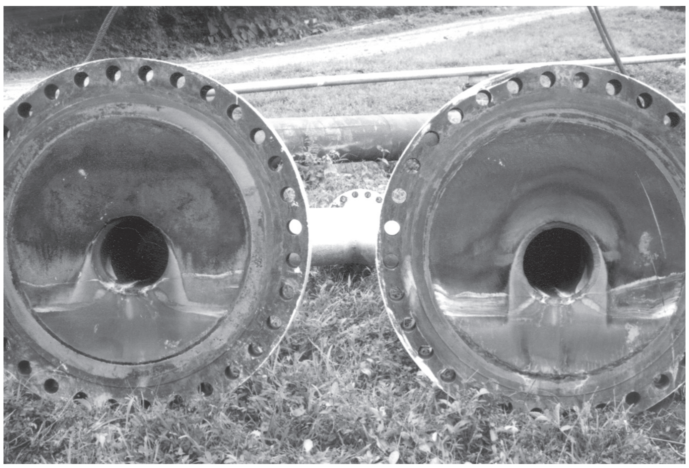

Figure 7. 1R8D modified solid trap inlet flange.

Figure 8. Modified solid trap outlet flanges.

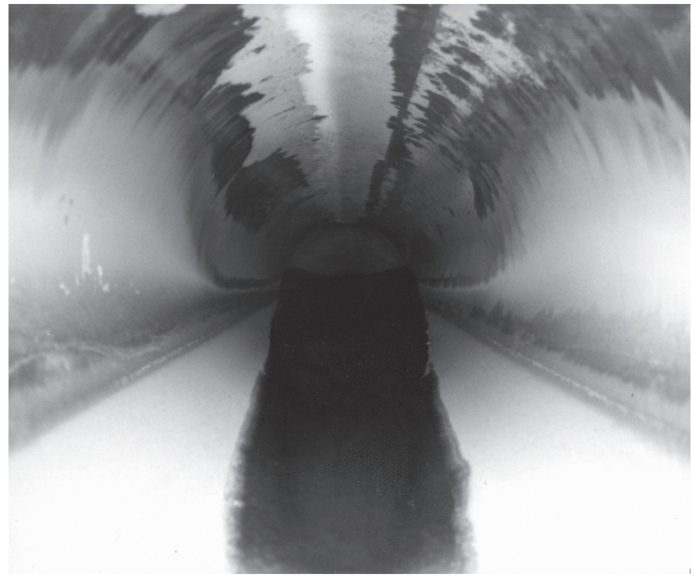

Figure 9. Inside the modified solid trap A inlet.

Figure 10. Solid debris taken from the MST.

Figure 11. Solids debris collected from the MST.

Modified Solid Trap Efficiency Evaluation

Well 1R8D modified solid trap was almost totally filled near the baffle plates when opened. In fact, it is suspected that some of the solids were already partly carried over by the brine into the well bore based on the profile of the solids that was deposited inside the solid trap. Deposition was significant since the utilization of the solid trap until it was opened was only167 days from commissioning. With the 3,445 kgs of solids collected, this translates to at least 20.6 kg/day of solids that were captured by the solid trap. If this amount were not

Figure 12. Debris found at the MST drain box.

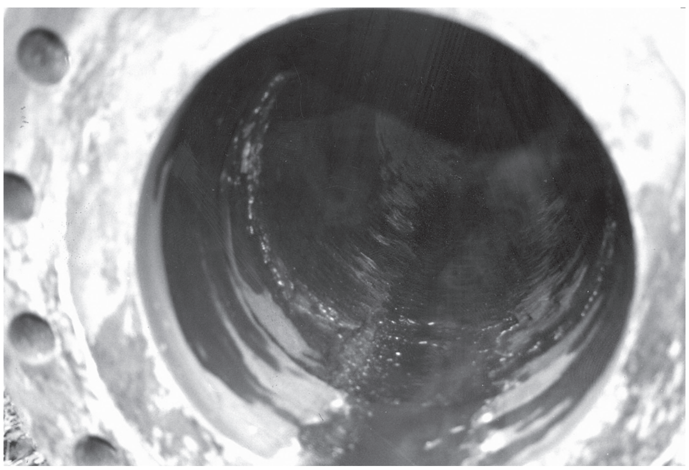

Figure 13. Few debris collected at the main RI line.

removed from the brine, it is likely that the capacity of 1R8D would have eventually significantly declined. These solids will fill the wellbore permeable zones like what happened to 1R3D and eventually drop its capacity.

The presence of amorphous silica in the collected debris is most likely caused by catalyzed polymeric silica formation. The silica saturation index (SSI) of the brine currently injected to 1R8D has a level of 1.07. At this level, silica deposition is considered minimal and tolerable based on historical data and the 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 iron. 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: $(\text{-SiOH})_m + Fe^{3+} = (\text{-SiOH})_n Fe^{3-n} + nH^+, Q_{n.}$

The megascopic analysis of the solids that were collected at the solid trap showed that it was 20% composed of magnetite (Fe_3O_4). Magnetite is in the form of Fe^{3+} in free ionic form. If this would be given enough time to react with the silica in the brine, this would eventually form globules of polymerized silica which in the long run would block the well bore. Removing the bulk of the source of ferric ion in the solution before it will fully react with silica would prevent the possible polymerization of silica. This is where the 1R8D modified solid trap would become more beneficial.

However, based on observation during inspection there is a limit in the capacity of the modified solid trap to capture the solids. Its efficiency would be reduced when the solids would start to build-up and begin filling-up 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. Also, bi-annual inspection and cleaning should be conducted.

Summary and Conclusion

The old solid trap (20" X 6 m) configuration installed in 1R8D proved ineffective in capturing the solids that are washed from the steam. The inspection of the main brineline showed that the debris did not settle along the line nor in the old solid trap as the minute solids were easily carried over by the brine down to the wellbore. These carried over solids may have accumulated in the permeable zones of the well thus showing an increase in wellhead pressure of the well. The observed initial tightening of 1R8D was attributed to the accumulation of the solids at the wellbore 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 to 1200 from 4500) of the brine allowing it to settle first before injecting the brine into the well.

The solids collected at the solid trap are composed of polymerized silica (50%) and corrosion products (40%) composed of magnetite and hematite. The corrosion products are similar to those washed upstream of the separator vessels. The total weight of solids collected from the modified solid trap was 3,445 kgs for an estimated deposition rate of 20.6 kg/s per day. Catalyzed or enhanced polymerization of silica most likely occurred since the brine is enriched with magnetite. This became a major factor in the decline of the injection capacity of the well. Removing the bulk of the solids from the solution before being injected would greatly reduce its potential to polymerize. Indeed, the modified solid trap served its objective of removing the minute solids carried by the brine.

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