RECENT INNOVATIONS IN PIGGING TECHNOLOGY FOR THE REMOVAL OF HARD SCALE FROM GEOTHERMAL PIPELINES

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ABSTRACT

Scaling of production lines and especially injection pipelines and pipelines to brine ponds is common in many geothermal power operations. Previous works by Stock (1990) and Brown (1995) have discussed methods to monitor and calculate scale build-up in injection lines by pressure drops and Klein (1995) recently discussed methods for predicting and suppressing scaling in reinjection lines and wells. These writers have mentioned the process of pigging to remove scale deposits, but the geothermal literature is virtually devoid of information related to the use of pigging operations to remove geothermal scale in pipelines. In developing new and innovative tooling to tackle the extreme pipeline scaling problems of the Salton Sea geothermal plants, E-P & Associates has gained a wide range of experience in removing very hard scale. By implementing a program of regular monitoring of injection lines as proposed by Stock, Brown and Klein and the scheduling of regular cleaning events using improved pigging techniques; pigging operations no longer need to be viewed as a dreaded event, but just routine maintenance.

1.0 INTRODUCTION

The Salton Sea geothermal operations experience elevated levels of scaling due to the hyper-saline brines produced fiom the Salton Sea geothermal field. These hyper-saline brines exhibit a total dissolved solids concentrations (TDS) ranging fiom 15 to 30 wt% (Gallup and Featherstone, 1993). Iron silicate scale is deposited fiom these brines particularly in the surface brine-handling equipment operating below 200°C. The scale is composed primarily of hydrated silica and iron oxide fiactions exhibiting various iron and silicon ratios, and appears as a black-brown, vitreous solid resembling obsidian. Minor constituents present in the scale include transition oxides or sulfides and alkaline earth oxides (Gallup, 1989). Needless to say these scales are very hard and deposit at a rapid rate as shown in Photo #1. Salton Sea plant operators have developed, tested and installed various methods of controlling these scaling conditions, including: Ph.-Modification, crystallizer-clarifiers and Line Mining (Gallup et al., 1995). All of these methods have proven successful to some extent in reducing scaling in reinjection pipelines and extending the period between cleaning of the injection wells. Nonetheless, reinjection pipelines continue to require regular maintenance, as well as, periodic reboring of injection wells.

Photo #1. An example of the extreme scaling conditions that can sometimes be encountered in injection lines that have not been regularly monitored or cleaned.

The process of learning to remove the very hard and tenacious pipeline scales encountered in the Salton Sea plants has been a long and exasperating period for both the operators and the cleaning contractors. Various methods were tried beginning in the mid to late 1980's using pigging technology developed for the oil and gas industry, and hydroblast cleaning. The hydroblasting technique is discussed briefly and illustrated in a paper by Hurtado related to scaling problems encountered at the *Cerro* Prieto plants. Brush pigs that had proven successful in removing soft scales in other geothermal operations had little affect on the Salton Sea scales and hydroblasting proved to be time consuming and expensive. Initial cleaning programs at the Salton Sea plants showed that new tools and concepts were required to stand up to the rigors of the scales encountered in these lines.

2.0 EARLY PIGGING TOOLS

The early pigging tools although appearing robust proved to be little match for the scale build-up found in the Salton Sea pipelines. Brush pigs, poly pigs, and various styles of "hard scale" pigs were tried. In most cases the brush pigs required multiple passes through the lines and the use of cool brine to propel them; usually the results were not satisfactory. The hard scale type tools had several problems; they were guided through the pipeline by sets of fixed guide rollers and they were propelled by soft, flexible propulsors. These tools cleaned the lines but only with much effort and in many cases they exited the lines in pieces. The main problems observed were: 1) the breakage of the front guide rollers, 2) the rapid deterioration of the propulsor materials, and 3) the inability to accurately track and locate the tool in the lines. When the rollers broke due to encountering thicker and/or harder scale deposits or traveling through sharp turns, the tool could then dig into the scale and lodge or become hung-up in turns. Sticking the pig then requires that the line be cut open, the pig removed and repaired, and the line welded back together. This process can take anywhere fiom 6 to 12 hours and could sometimes be repeated two or three times per line cleaning! The second main problem centered around the propulsors. The leather or rubber materials wore quickly when rubbing along the scale in the line or deteriorated due to the high temperature of the brine and the saline conditions.

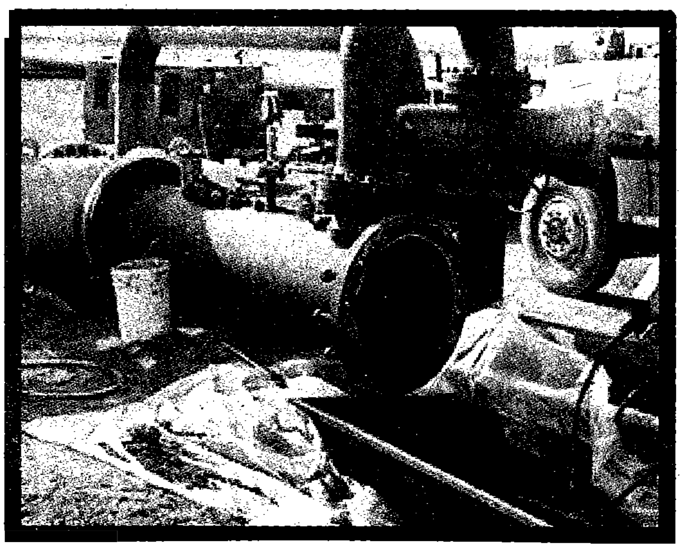

Photo #2. One style of pig launcher showing the launch tube, temporary piping to supply brine to drive the tool, and valving to isolate the launcher from the main line.

3.0 RECENT TOOL DEVELOPMENTS

Based on early experiences, E-P & Associates began to develop a new pig design to make them more rugged, but also to improve upon the basic concepts. Overall the new tools were developed to make them easier to manufacture, repair, operate and track, but also to incorporate pivotal roller supports, metal propulsors and tool guides.

3.1 Pivotal Roller Supports

As discussed earlier, one of the main problems was with the pigs sticking in the lines due to the breakdown of the rollers. This was traced back to the fact the rollers were solidly mounted on the pig body and broke when they encountered very hard deposits of scale or as they slid through the turns in the pipeline. To solve this problem the rollers are mounted on pivoted supports that allow them to compensate for extremely hard andor irregular scale deposits and to give the tool some flexibility as it moves through turns. The roller carriers are sprung by a heavy metal nose piece that is tensioned through a cable arrangement and a series of spring washers. During travel through the pipeline in straight sections, the guide rollers are raised in the normal position and the roller carriers are aligned with the tool. This arrangement of pivotal rollers maintains the pigging tool in a centered, stable path in the straight sections of the line; while allowing the rollers to move and adjust to scaling conditions and directional changes. By maintaining the rollers in good condition, the pig is less likely to stick in the line.

3.2 Metal Propulsors

The second obvious problem with earlier pig designs was the propulsors. The propulsors must serve a number of functions for the pig to operate properly and they must do so in a harsh environment. The propulsors must seal against the pipeline walls or scale surface, so that pressure applied behind pig will drive the tool forward. The propulsor cannot totally seal off the fluid flow, but must allow some amount of fluid to "by-pass" the tool to flush scale chips ahead of the pig. This is a fine balance and the balance must be maintained fiom the start of the pipeline to the end. If the propulsors by-pass too much fluid the pig will not move forward, or the pig will move some distance and then stick as the propulsors wear. If it does not by-pass enough fluid the chips will build up in fiont of the pig, normally in an up run or in an expansion loop and then the pig will also stick. Early propulsors of leather, rubber and synthetic rubber accomplished all of these tasks, but they did not do them consistently. The soft materials which 'fit tightly at the start of a run wore out half way through the run and the pig stopped. Some materials deteriorated under the temperature and saline conditions of the brine and turned to mush, others baked hard and became brittle, like particle board In either condition the propulsors failed and the pig stopped. Finally, when hard spots are encountered, the normal procedure for freeing the pig is by surging it or bumping it with variations in the line pressure. Pressure of up to 400 psi is sometimes applied behind the pig to break it fiee. In these cases the early propulsors were shredded or tom to bits. A stronger propulsor material was definitely needed. After numerous attempts, the decision was made to try all metal propulsors.

The metal propulsors are machined fiom steel disks and then cut into sections. These sections are then hinged onto the propulsor assembly. Sections of the propulsor can move independently or as a unit, as tool movement though the pipeline and scale conditions dictate. The steel propulsors have proven far superior to any material yet tried. The propulsor sections show little wear even after operating in heavily scaled conditions and after being repeatedly rocked with high pressure. Additionally, the metal construction shows no ill affects fiom high temperatures or saline solutions, so the pigging operation may extend over an longer period of time if required. Occasionally plant mechanical problems may develop that cause a pigging run to be delayed or stopped; a pump goes down, electrical switching gear is lost, a valve fails, etc. Previously the propulsors would be lost after several hours in the brine solution. This is no longer a problem with the steel design and thus expands the operating parameters of the tool.

Photo #3. Pig tracker being attached to the tool in the launch tube prior to closing up the launcher and beginning a cleaning run.

3.3 Tool Guides

E-P's latest design incorporates the addition of small guides to the pig. Over a series of cleaning projects, it was determined that the tool could stili hang-up in some turns and fittings even if the guide rollers and propulsors were still working perfectly. To overcome the potential for the pig to dig into tight turns or become lodged in a valve or fitting, a number of small guide plates were added to assist the tool in traversing these trouble spots. The addition of these guides has greatly improved the ability of the tool to pass through flanged couplers and valve bodies.

At this point in time, E-P & Associates has patented, state-of-the-art, pigging tools designed specifically for the removal of hard scale deposits as found in the geothermal industry. In addition to the design features outlined above, E-P has developed a patented tracking device that allows the pig to **be located** within the pipeline when it is moving *or* **stationary.** This unit *can* be operated in hot brine fluids indefinitely, **a** great improvement over previously available tracking *systems.*

4.0 PIGGING OPERATIONS

What makes for a *good,* efficient cleaning operation? What are the factors involved and what is required?

E-P & Associates' experience has shown that a pigging operation is a team effort. The plant operators must be committed to the cleaning method, understand it and work with the contractor to get the job done. A good, coordinated effort on the part of the operator is required so that time is not wasted. The pigging program needs to be a specific task in its **own** right with operator staff assigned to the project, rather than an adjunct to other maintenance that is going on during a given shut down period. With good cooperation and understanding *on* the part of the plant staff, cleaning operations invariably run smoother and get done on time. The cleaning contractor cannot work in the vacuum of the plant with limited operator commitment. When attempted the results are usually poor. The operator needs to prepare in advance for the cleaning program; pig launchers and jumper lines may need to be installed, waste catch basins or Baker Tanks need to be constructed or positioned, pumps should be tested and run to capacity, all valves in the circuit tested for operation, etc. If it can break or fail, it will do so during a pigging operation! Test it and check it before the cleaning contractor arrives. The pressure requirements based *on* the density of the scale is shown in Fig. 1 and the flow requirements for various size pipe diameters are shown in Fig. 2. These charts are based on past experience with lines fiom 8" to 24" and the very heavy scales of the Salton Sea plants. Bigger lines and lighter scale (by weight) may allow these requirements to be reduced, depending on each individual situation.

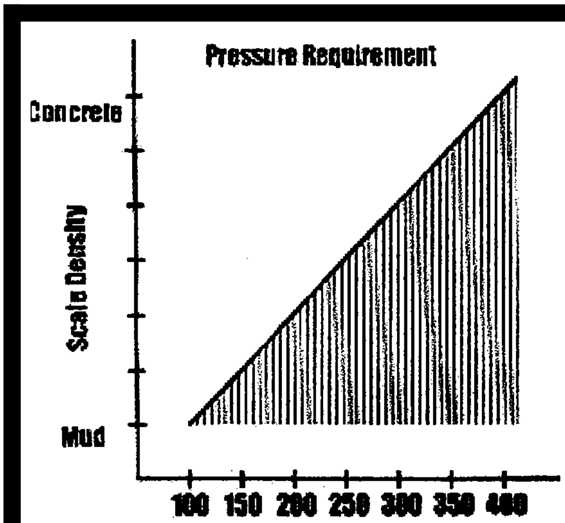

Figure 1

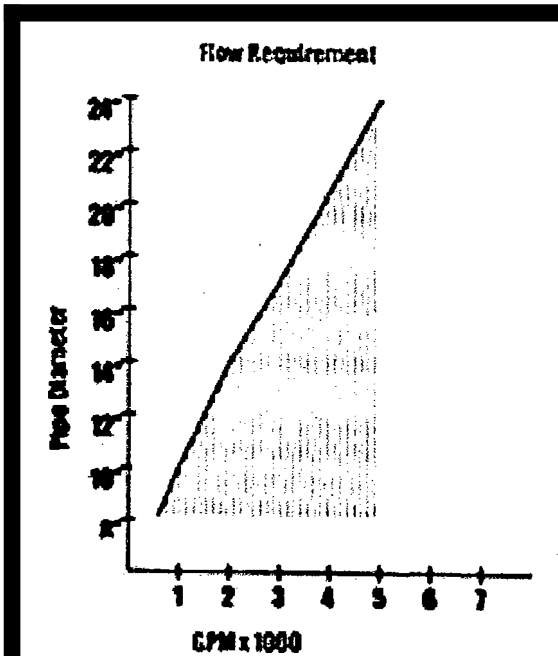

Figure 2

Pigging technology as a method for removing scale from geothermal lines seems to have been poorly received over the past ten years in some industry circles due to the poor performance of tools designed for the oil and gas industry being transferred into geothermal applications. These days should now be behind us. The geothermal operators are becoming very sophisticated in operations and maintenance, and better understand the scaling and corrosive environment in which they work. Pigging also received a poor reputation because it was used as the option of last resort in many *cases* and it was doomed to failure with the earlier tools. **When pigging is used as part of a regularly scheduled program of maintenance, it will cost-effectively clean and remove scale from geothermal Lines**

Both Stock and Brown in their papers on the monitoring of scaling in injection lines recommend that the lines be regularly checked for pressure drops to determine the rate and amount of scale build up. This data will only begin to have meaning after a number of years and after a number of cleanings have been done to correlate the information, but once established it will help plant maintenance personnel and corporate cost analysts to determine the most efficient cleaning cycle for each line.

Klein further recommends the following be considered when designing, rehabing or building new plants and line:

- Design the injection system to minimize the residence time and avoid turbulence.
- Install pressure ports on injection lines to allow monitoring for scale-related impedance.
- Install inspection ports and scaling coupon ports on the injection lines.
- Install ports at both ends of the injection lines to allow inserting and retrieving the pig

Cleaning operations will vary fiom plant to plant and line to line. Depending on the fiequency of cleaning and the density of the scale deposit, some lines can be cleaned in one pass and others may require multiple passes. When a line is to be cleaned in one pass, the scale cannot usually be more than about 1" to 1.5' thick and not extremely hard. The tool is then sized about .5" smaller than the line diameter. The tool then has room to work and travel in the line with less chance of sticking and the scale that remains on the pipe wall, will in most cases be fractured and fall off after the pig has passed through. The remaining scale is then flushed out of the line with high flow over the next several hours after the tool has been removed fiom the line.

Lines that have not been cleaned recently or with very hard scale deposits may require multiple passes to remove the scale. In this case the tool is sized for the first pass to clean off the rough interior layer scale and to establish a clean, round bore for subsequent passes. The E-P tool is normally sized up in increments of 3/8" on the diameter per pass, but it has been operated at up to 3/4" cut on the diameter per pass in very hard scales. The increases in tool size are accomplished by assembling the pig in different configurations using bigger scrapper plates, guide rollers and rollers supports. Very hard scale build-ups of up to 2" thick in a 22" line may require six to eight passes of the tool to remove the scale.

5.0 CONCLUSION

The state-of-the-art in geothermal power generation is steadily being advanced and along with that are coming improved methods for dealing with the scaling and corrosion problems associated with the industry. One area that has been of continued concern is the removal of scale build-up from pipelines in and around the power plants, particularly the production and injection lines. Pigging technologies fi-om the oil and gas industries and hydroblasting did not provide satisfactory solutions to the problem, leading to advanced pigging technologies being developed for the geothermal industry. E-P & Associates has developed pigging tools specifically designed for hard geothermal scales and they have acquired a wide background of experience in dealing with heavily scaled injection lines. Further improvements in the monitoring of scale build-up in lines through the use of pressure drop analysis and installation of inspection ports will allow for improved operation and maintenance.

With the acceptance of pigging as a regular maintenance practice, the industry will:

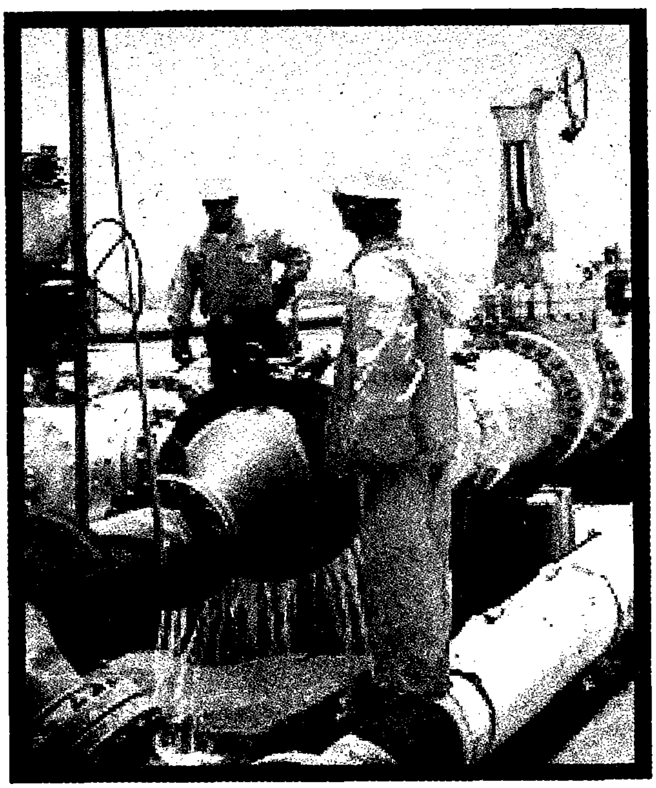

Photo #4. Line being opened upon completion of a cleaning operation. Photo shows the reducer bell that attaches the main line to temporary waste disposal piping and the isolating valve.

- have less down time due to cleaning operations
- reduce its daily operating costs (injection pumping costs) by maintaining cleaner lines
- allow for more efficient plant operations, and
- allow for the design of longer pipelines to better utilize production and injection fields.

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