

TECHNICAL ANALYSIS AND FEASIBILITY OF SCALE REMOVAL IN THE GEOTHERMAL WELLS AND SURFACE PRODUCTION FACILITIES USING TRUE FLUIDICS OSCILLATOR (TFO)-PULSATING WAVES METHOD TECHNOLOGY

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Abstract

Mineral deposition or scale is the main problem faced in geothermal energy management activities that occur in wells and in production facilities that cause a decrease in power plants' capacity. Scales are formed naturally and cannot be prevented because it is associated with reservoir and operational conditions that are widely found in Indonesian geothermal systems, predominantly liquid dominated ones, therefore the advantaged technology is needed to clean the scale (scale removal) so that the ability of wells and power plant capacity is maintained. This research aims to offer the alternative method for scale removal using the True Fluidics Oscillator (TFO)-Pulsating Waves Method. This method combines mechanical processes, chemical processes, and wave processes simultaneously to provide solutions to clean scales inside or outside the production casing or perforation zone. This oscillator creates pulsating pressure waves within the wellbore and formation fluids. These pressure waves help to break up any type of near-wellbore damage and restore the permeability by carrying the fluid past the wellbore into the formation. The pressure waves expand in a spherical fashion from the point of origin providing 360° coverage while moving the tool across the interval. The TFO is not affected by standoff from the surface to be cleaned and TFO efficiently transfers the kinetic energy of the fluid pumped to the damaged zone. The use of TFO in conjunction with any chemical treatments will greatly enhance chemical surface contact area. Technical and economic analysis of the operation of TFO is needed to be applied appropriately to the condition of geothermal systems in Indonesia by using examples of cases in the Dieng Geothermal Field to know the feasibility of the technology.

Keywords:

Scale Removal, Inside Casing, Outside Casing, Liquid Dominated, True Fluidics Oscillator, Pulsating Waves Method, Feasibility.

I. Introduction

Scaling is the most classic problems in the geothermal industry since it could deplete the electricity production and increase the maintenance cost. The composition of the scale in geothermal plants is commonly very complex and depends on many parameters, such as the temperature and pressure of the fluid, the history of water rock interactions and the operating conditions. Among the different minerals susceptible to deposition, silica and calcite are the most common and the most difficult to remove. However, while calcite has been mostly troublesome for production well management, silica is considered “dangerous” for reinjection wells and some parts of the surface conduits transporting the brine (Grassiani, 2000). Amorphous silica is one of the major and most common scaling problems as its solubility decreases with decreasing temperatures. Depending on the conditions, amorphous silica scales may form anywhere from the production wells, surface facilities to downstream of injection wells. The scaling problem is inherent to most liquid dominated geothermal resources. Generally as aquifer temperatures rise, scaling problems would be expected to occur along the extraction system. In case of scaling in Dieng geothermal power plant, it can reduce the production from 60 MW to 42 MW (Minkatsu, 2006).

A mitigation to prevent formation of the scales is essential. Although, silica scaling might not be able to completely avert, controlling the formation can be an alternative solution. Scale deposition across perforation tunnels is an ongoing and serious problem encountered during the lifetime of production geothermal wells. However, the perforation tunnels create a flow path between the formation and wellbore. The pressure difference between them can drive surge flow, either from the formation into the wellbore or from the wellbore into the formation. Deposited particles in the perforation tunnels hinder the flow of fluid or steam leading to significant increase in pressure drop and therefrom dwindled production. If the well is not treated by removing, or at least reducing, the deposited scale, the

mass production rate could ultimately become zero. Scale deposits usually form due to the crystallization and precipitation of minerals dissolved in brine water. In general, scale is deposited in formation, wellbore, casing, flow-line and power plant facility. The common scale removal treatments technology that have been implemented are chemical scale removal (CSR) and mechanical scale removal (MSR), the several factors affect the type of treatment to be considered such as the amount of precipitation and costs.

CSR, the chemical washes are used to attack soluble deposits across perforations; however, normally fresh water is pumped first before the designated chemical is injected. Various chemical solvents dissolve hard scales, depending on their mineralogy or geochemical contains. The major concern in treating scale deposits is allowing sufficient time for the treating fluid to reach and effectively dissolve the bulk of the scale material. Treating fluid must dissolve most of the scale for the treatment to be successful (Hill et al., 2000) Usually, time required for treating scale deposits is determined experimentally. After allowing sufficient time for scale to convert, the sludge is washed or pumped from the well or dissolved by an acid. CSR will take time to get the right implemented type of chemical to be matched with the character of scale composition and has to wait for another time to dissolve it.

MSR, is based on creating a dynamic underbalance in which the wellbore pressure is less than formation pressure. The underbalance surge is created when surge chamber is allowed to accept wellbore fluid and debris. This creates a low pressure and is propagated throughout the wellbore. The underbalance surge can clean the perforation in two main ways (Bolchover, 2006). First, the debris can be transported out of the perforation tunnel. Second, the damaged zone can be cleaned up either by mobilization of fines or by additional failure of the damaged rock. The tool, similar to that assessed by (Harive et al, 2011) containing surge vents and chambers, is utilized to create and optimize dynamic underbalance conditions. Thus, in a few hundred milliseconds after the tool detonates its perforating gun; the wellbore pressure is dropped significantly below static formation pressure, creating a dynamic underbalance. The created differential pressure flushes back perforating debris and crushed rock to clean the perforations. The perforating assembly can also be modified with increased gun volume and addition of specially designed vents and surge chambers to optimize pressure surge behavior. As a result, MSR treatment creates a dynamic underbalance regardless of initial pressure conditions. It is normally compatible with or can be performed by tubing-conveyed perforating, slick-line, wire-line or coiled tubing.

Both types of CSR and MSR treatments are apparently not able to handle scale deposit problems that are located outside of the slotted liner or production casing. CSR and MSR are only able to clean and dissolve the scale inside the casing so that the scale deposit will be quickly reformed. Therefore in this paper we will introduce other types of treatment which are a combination of CSR and MSR so that it can dissolve scales that are located outside the slotted liner to enter penetrate into the formation so that the life time of the geothermal production well becomes longer. The technology is called True Fluidics Oscillator (TFO).

II. True Fluidics Oscillator (TFO)

True¹ Fluidics² Oscillator (TFO) is controlled by a fluidic switching tool to diverts fluid flow with no mechanical moving parts. Flowing fluids have tendency to preferentially attach to a nearby surface and remain attach there to until the fluid stream is disturbed. A stream splitter in the TFO tool is designed to cause the fluid flow to adhere to and flow down one passageway, while also creating enough of a disturbance in the fluid to cause the flow to switch to the opposite passageway. As long as the flow rate through the TFO tool is above the activation rate for that switch, the flow will cycle on and off between the two outlet ports. The TFO tool uses a bi-stable oscillator design based on the *Coanda affect*.³ The TFO technology use this positive pulse design to guarantee the creation of the fluid slugs used to generate the pressure pulses/waves.

The TFO (Fig. 1) is used in conjunction with through coiled tubing, conventional tubing, wash pipe or drill pipe. Fluid oscillation produces emissions of alternating bursts of fluid that create pulsating pressure waves within the wellbore and formation fluids. This oscillator creates pulsating pressure waves within the wellbore and formation fluids. These

¹ No downhole mechanical moving parts.

² The technology of using the flows and pressures of fluids in sensing, control, and information-processing systems with no moving parts., (American Heritage® Dictionary of the English Language, Fifth Edition. Copyright © 2016 by Houghton Mifflin Harcourt Publishing Company. Published by Houghton Mifflin Harcourt Publishing Company)

³ Coanda Effect or wall-attachment effect, the tendency of a moving fluid, either liquid or gas, to attach itself to a surface and flow along it. As fluid moves across a surface a certain amount of friction (called "skin friction") occurs between the fluid and the surface, which tends to slow the moving fluid. This resistance to the flow of the fluid pulls the fluid towards the surface, causing it stick to the surface. Thus, a fluid emerging from a nozzle tends to follow a nearby curved surface—even to the point of bending around corners—if the curvature of the surface or the angle the surface makes with the stream is not too sharp. Discovered in 1930 by *Henri Coanda*, a Romanian aircraft engineer, the phenomenon has many practical applications in [fluidics](#) and [aerodynamics](#).

pressure waves break up any type of near wellbore damage and restore and enhance the permeability of the perforations and near wellbore area. The desired treatment fluid (acid, water, seawater, diesel, nitrified, fluids, etc) is pumped down the tubing through the TFO Tool.

The oscillating pressure waves generated by the TFO tools are not affected by standoff like conventional jetting or velocity tools. The kinetic energy of the pressure pulse travels through the wellbore fluid with no appreciable energy loss. It is only after the pressure wave contacts the formation that this energy is dumped and the process of removing the near wellbore damage are initiated. These pressure waves expand in a spherical fashion from the point of origin, which ensures that 360-degree coverage is ensured while moving the tools through the interval.

The FOT has a downward Y-shaped passage, in which fluid will tend to follow only one of the branches, causing the other branch to have a vacuum state through a hole connecting the two branches. The vacuum will switch the flow from one branch to the other, causing the vacuum to switch to the other branch. The continuous switch of flow creates disturbance in the surrounding fluid and creates pressure waves at ~200 Hz, suitable for use as a treatment tool.

The powerful pressure waves exert cyclic loading on near-wellbore (NW) damage as the tool is reciprocated through the interval. As a result, the FOT can break up many types of NW damage, helping restore and enhance the permeability of the perforations and NW area. The cyclic loading also enhances the use of chemicals by breaking up damage to increase the contact area.

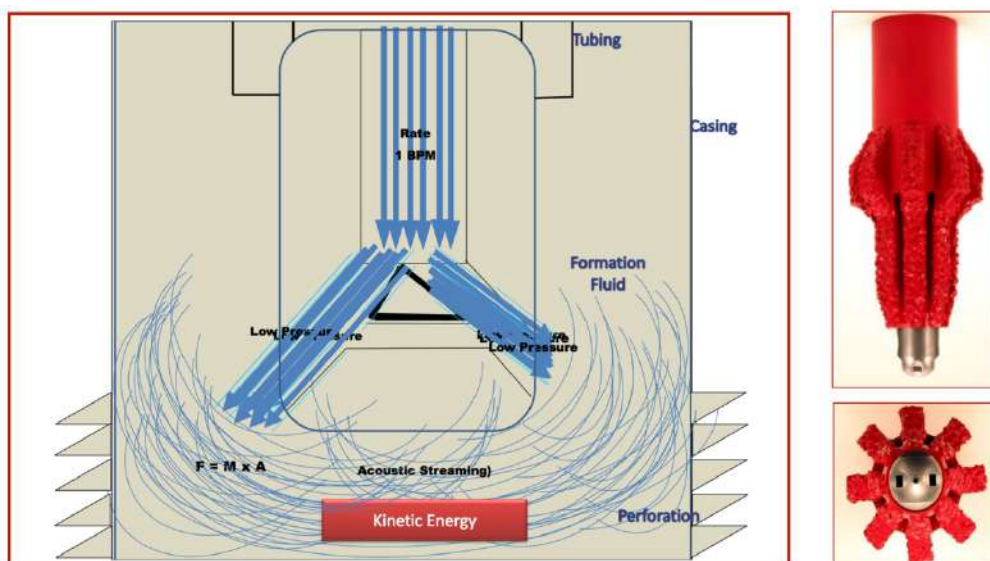


Figure 1: PerfClean® - True Fluidics Oscillator (TFO) Tool

The treatment fluid is pumped through CT, DP or Tubing, then enters the FOT body and is accelerated into the fluid oscillator. The fluid stream enters the oscillator and preferentially attaches to the outer wall of one of the fluid passageways. The flow continues down the selected passageway to the outlet. As the flow passes a cross-channel, a low-pressure area is created, causing the main fluid stream to be interrupted and the flow to switch and attach to the other fluid passageway. The switch begins to oscillate, which causes alternating “bursts” of fluid to be ejected into the wellbore. As each burst is ejected, it forms a compression wave within the wellbore fluid. Compressive loading occurs when the wave enters the perforation tunnel or the open hole section and contacts the formation face. As the wave passes through the formation and is reflected back, it induces a tensional loading on the skin damage.

The Pin Point streaming induced by the oscillator focuses the treatment fluid and tool energy to the immediate area of the tool, which allows for treating specific intervals. These tools are not affected by stand-off distance. There are no moving parts. They do not rely on cavitation to create pressure waves. There are no packer elements to fail. Unlike mechanical tools, which suffer from high-energy losses, the TFO maximizes the energy potential of the pumped fluid. Actual production history shows that while competing tools and technology have similar production increases immediately after treatment, their "increases" drop off dramatically in 2-3 weeks. The continuous cycling of these pressure waves causes the skin damage to reach its fatigue failure point. As skin damage is removed, the pressure waves penetrate deeper into the formation (Figure 2).

Treatment design and execution varies according to well conditions and the customers goals whether you need simple wellbore clean outs or primary stimulation of producing zones. The TFO is currently made in two sizes: 1.25” and

1.50". OD. The small size of the tools enables easy passage through smaller-sized restrictions while still effectively cleaning wellbores and removing near-wellbore formation skin damage.

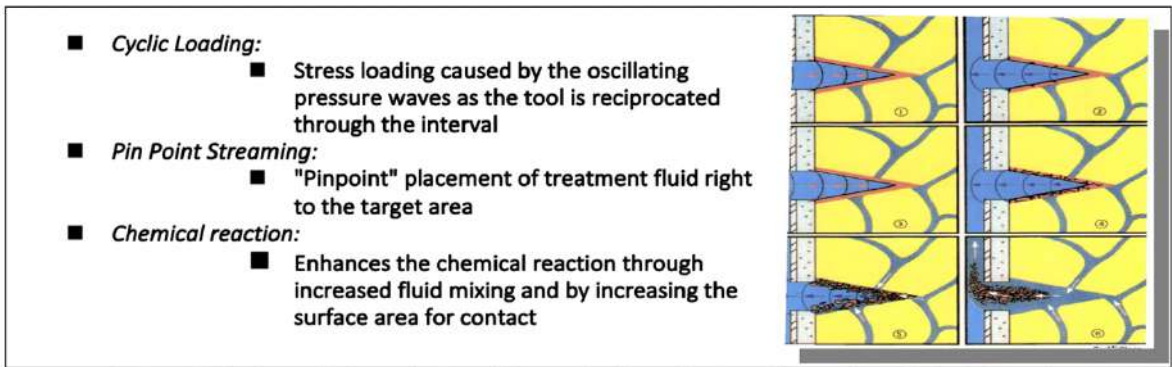


Figure 2: TFO Cleaning Mechanism, Joint Strength between Cyclic Loading, Acoustic Streaming and Chemical Reaction

II.1. Case Histories

The following two case studies document the success of the damage-diagnostic analysis by TFO treatment system. Following the pipeline project (Case History #1) for heavy scaled surface production facility, another project was initiated in Dieng Geothermal Field (Case History #2) of wellbore scale removal treatment.



Figure 3: TFO Stimulation - Jointed Pipe Operation (Rig 550 HP) in Dieng Field

Below TFO stimulation was performed using 2" OD coiled tubing. TFO with StimMill was run into the well to clean out scale bridges and hard packed fill. The treatment fluid (filtered fresh water) was pumped down the tubing thru TFO and the combination of the cutting action from the StimMill with pulsating pressure waves created by TFO allows the operator to reach target as predicted. After reaching the desired depth, the StimMill was used to wash over and stimulated the near wellbore area while being tripped out of the well.



Figure 4: TFO Stimulation - Coiled Tubing (2-in OD coiled tubing) Operation

II.1.1. Case History #1 Surface Treatment

The 10" ID injection flowline with full of Barium Sulphate scale deposit was found in Rex Energy, Bridgeport Illinois, USA. The total length of the pipeline was 3600 feet long. The TFO treatment was implemented using coiled tubing to convey TFO tool inside the scaled 10" ID pipe and pumped fresh water at 1 bpm. (Fig.3).⁴



Figure 3: TFO Treatment for 10" Injection Flowline with Barium Sulphate Scaled Up, Illinois USA, 2008

¹ Reported by Andy Rowe, DHFS Technology LLC, Houston, USA, 2008 as a final report of TFO treatment in Rex Energy, Bridgeport Field, Illinois, USA.

II.1.2. Case History #2 - Downhole Wellbore Treatment (Oil and Gas)

Below are example of cost effective method applying TFO to increase injection rate in water injector wells. When dealing with high injection rate and high permeability wells will require high treatment rates to divert effectively and without proper diversion the injection rate of the targeted zone will not be improved. Pin point placement will also minimize chemicals usage.

Location	Well Name	Formation	Injection Rate (BWIPD)		Increase (%)	Treating Fluid
			Before	After		
Indonesia	Well 8E-33	Sandstone	8,500	15,000	76	15% HCl
	Well 8E-44	Sandstone	2,500	5,300	112	15% HCl
	Well 8E-32	Sandstone	9,200	22,000	139	KCl Water
	Well 7E-95	Sandstone	12,800	21,000	64	KCl Water
USA	Well NA	Sandstone	720	3,600	400	KCl Water. The surface Injection pressure was 250 psi(before) and 50 psi (after)

These wells below experience with gas deliverability decline over the lifetime of the well for a variety of reasons but most often decline is caused by near-wellbore skin damage from either built up scale or drilling fluid damage.

Location	Well Name	Formation	Production Rate (BOPD / MMCFD)		Treating Fluid
			Before	After	
Indonesia	L5A-238	Sandstone	0.8 MMCFD with Zero Water	Production after treatment was 4.0 MMCFD 350 BFPD	120 bbl 2% KCl and 60 bbl 15% HCL Acid
	BBT-03	Sandstone	Tight formation with 23 BOPD (after fracturing)	Post PerfClean treatment production increased to 34 BOPD, continued cleanup and stabilized at 43 BOPD	2% KCl brine treated with 3% non ionic surfactant
	W-09	Vulcanic Sandstone	0.39 MMCFD	3.1 MMCFD	70 bbl 15% HCL acid displaced with 2% KCl brine
	W-19	Vulcanic Sandstone	0 BOPD	120 BOPD	60 bbl xylene and 60 bbl paraffin solvent
Egypt	Well X	Sandstone	PerfClean tool: Ensuring Effective Treatment in Difficult Completions - 10 folds Productivity Increase. SPE 93987.		
UK	Well A-44	Sandstone	62% Productivity Increase compared to the other wells that were treated with same fluid treatment on same platform. SPE 81732.		

II.1.3. Case History#2-Dowhole Wellbore Treatment

The installed power plant capacity of the Dieng Geothermal field was 60 MW in 2004, Dieng's electricity production was depleted down to 20 MW on average in 2012, where steam comes from 4 production wells which are all located in the Sileri area. The limitations of the production well and the indication of problems in the wellbore such as the existence of scaling or the possibility of casing collapse made the operation of the well not optimal, as shown in Figure 4.

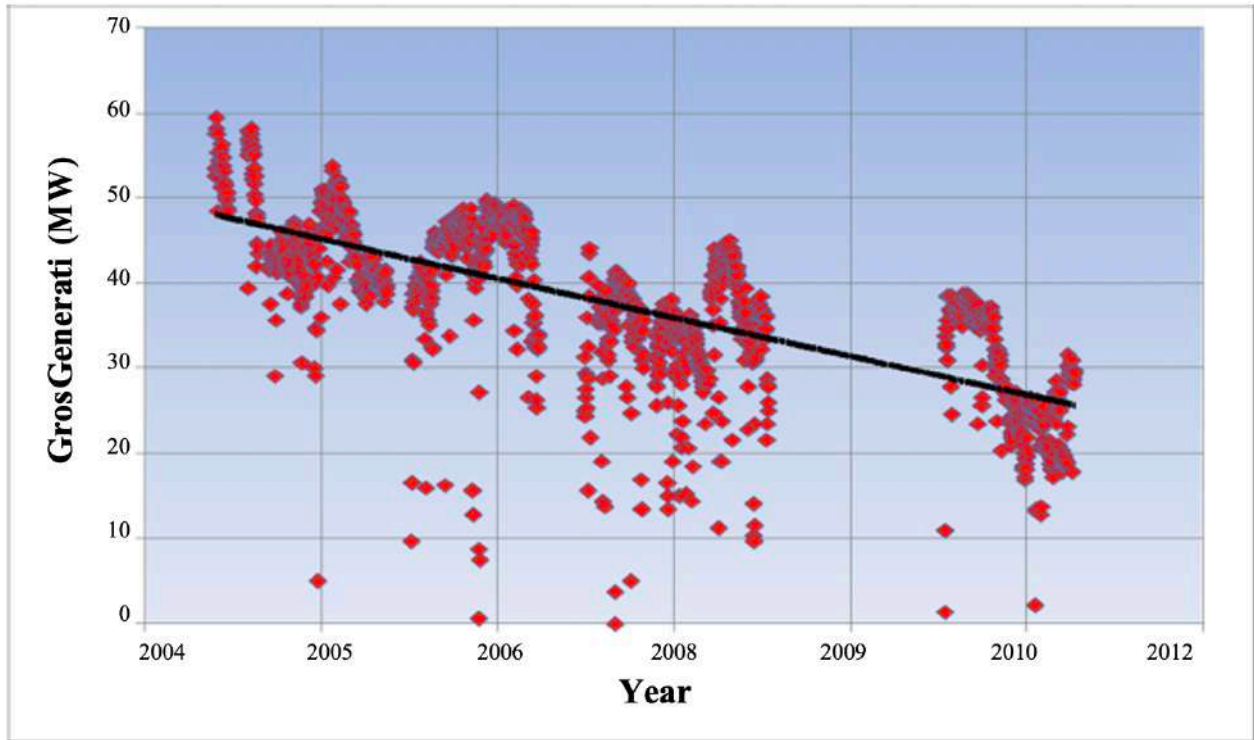


Figure 4: Dieng Electricity Depleted Graphic Trend Line

II.1.3.1. Candidate Selection

There were 8 well candidates chosen for a Geothermal Dieng field scaling cleanout project by using TFO technology (Figure 5). A team of engineers and geologists from the company and the service company was formed to determine which wells would benefit most from TFO treatment. The team identified wells based on current performance data and reviewed the historic well files and data from candidate- selection work performed in 2012.

A chosen candidate list was created and wells were ranked according to expected deliverability improvement (maximum deliverability minus current deliverability). Well Geothermal-7C (Red Triangle) was elected as a candidate well for TFO treatment to be applied. Well Geothermal-7C was start produced in 2007 with an initial capacity of 11.3 MW, in 2010 the production capacity was drop to 5 MW, workover job was performed to increase the capacity up to 8.5 MW but then significantly drop to 3.5 MW in 2012 before TFO was implemented.

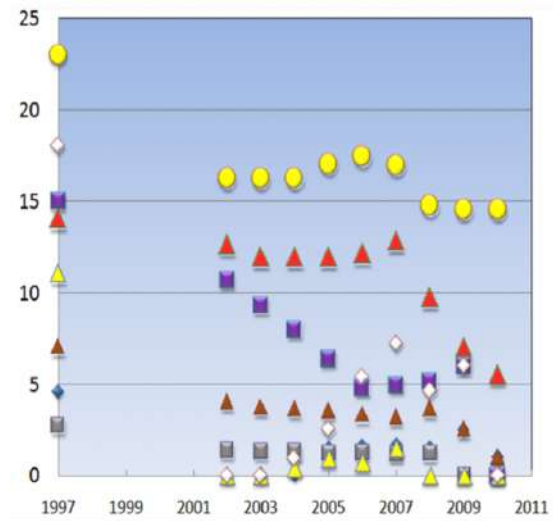


Figure 5 : Well Candidates Capacity Graphic line

II.1.3.2. Diagnostic Testing

The most important to identify the degree and type of damage that is causing the loss in geothermal's steam mass flow deliverability before any treatment is proposed or implemented. In Dieng the following diagnostic testing was applied to help ensure that proper damage-removal techniques were used to recover optimal deliverability. The diagnostic process included well data analysis during drilling or well test and downhole scale sampling, the high resolution downhole video (DHV) was not applied due to a cost concern. A solution research team then categorized and formulated treatment designs based on the diagnostic results of the sample analysis as the extremely important. Individual well potential was then determined from injection and withdraw historical performance data and well testing. The process also included measurable targets for deliverability enhancement. The following is a brief description of each diagnostic process used in the diagnostic testing.

II.1.3.3. Downhole Sampling and Analysis

In this case, the downhole sample analysis on all of the wells in the field were provided by company reveals the presence of a large amount of Galena, Siderite, Calcite and Dolomite in many of the wells.

II.1.3.4, TFO Treatment Performed & Result

The TFO treatment was performed in April 2012 with the following well information:

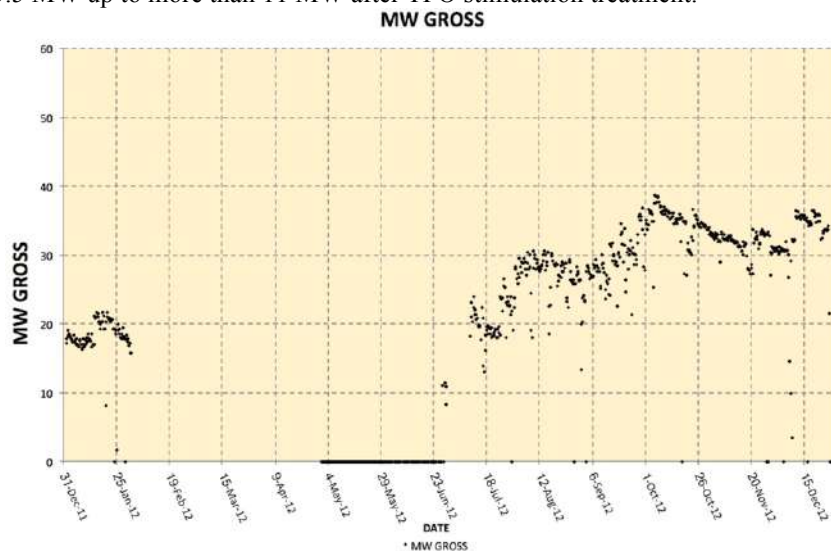
- Deviated well
- Rig 550 (thru an IPM company)
- Conduit: Drill Pipe 5.5-inch inside 9-5/8" Production Casing
- BHA : PerfClean 1.5-in OD (thread 1-inch 14 UN PIN) • X-Over 1-inch 14 UN BOX to 2-3/8" BOX • X-Over 2-3/8" PIN to Tubing Thread (Figure 6).
- Treatment Fluid: Fresh Water (pumped thru TFO to stimulate the well)
- Target zone (Total Lost Circulation) at bottom section of 9-5/8" slotted liner.

Running Procedure

- Pumping Fresh Water at 3 BPM (barrel per minute), reciprocated pipe every 2 joints across the target zones / PLC. Pump down fresh water in the annulus at 3 BPM to maintain fluid level.
- TFO stopped at 1926 Meters (this is around 241 meters above main target zone / TLC). Worked on drill pipe string and still could not move the pipe down. Decided to pump / stimulate TLC from this point pumping fresh water at 3 BPM for total of 4 hours.
- POOH. Continued with workover program.
- Heat up well in 48 hours then flow test.

Result

- Flow test result (after 2 days well's heat up) indicated that the capacity of Well XXX-7C was increased from 3.5 MW up to more than 11 MW after TFO stimulation treatment.⁵



⁵ Reported by DHFS Technology LLC, Houston, USA,2012 through DFI Indonesia as per internal discussion with Dieng Geothermal.

III. Conclusions

The TFO treatment technology is one of proper scale removal technology alternative to be applied in the geothermal industry, this system can use descaler chemicals or fresh water to dissolve and remove scales in wellbore or in surface facilities. The beneficial effects of the hole cleaning energy generated by the TFO are:

1. The oscillating pressure waves that lead to physical disruption of the damage/scales in the production zones;
2. The fluid flows induced by Pin Point streaming;
3. The enhancement of chemical reactions through greater surface contact area.

The TFO will reduce the volume of use of chemicals significantly, especially corrosive chemicals such as simple HCL-HF acid or descaler chemicals so that it will reduce the risk of damage to the casing, this system will reduce your cost accordingly.

The advance descaler chemicals are now available with their benign properties as being non-corrosive and non-damaging and have superior capability to dissolve amorphous silica, sulphate compounds and others common built up scales in the geothermal wellbore.

The TFO well treatment stimulation has been widely used in the oil and gas industry but is not yet familiar in the geothermal industry, so by re-engineering process it will be very suitable for geothermal applications. TFO is very simple to run using workover Rig, CTU (2" or greater OD) or Rigless by using 2-3/8" tubing or macaroni tubing with a heavy lifting tools such as crane to save on production costs.

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