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Well-to-Well Two-Phase Injection using a 10in Diameter Line to Initiate Well Discharge in Mahanagdong Geothermal Field, Leyte, Philippines

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ABSTRACT

Most of the wells in the Mahanagdong Geothermal Field need to be induced in order to discharge. This is mainly because the field lies at a much higher elevation of 700-900 mASL and therefore producing wells have a low water level at the wellbore. Added to that is the absence of gas and two-phase pressure build-up in most of the Mahanagdong wells.

To initiate well discharge in Mahanagdong wells with this condition, additional energy must be put into the water column of a static well to convert it to two-phase column and for pressure to build-up. There are several methods use for this purpose, namely; a) air (or gas) compression; b) gas lifting; and c) well-to-well two-phase injection. The most commonly used method at PNOC-EDC fields is the well-to-well two-phase injection.

This paper discusses in details the procedures of a well-to-well two-phase injection using two different diameter sizes of injection lines. Previous practice is done through the use of a 2” diameter injection line connected to the wing valve of each well. Using this line size, injection time is longer, ~ 2 days, with the chances of a successful discharge seldom achieved. In contrast, the use of a 10in diameter line has greatly reduced the time for two-phase injection and improved significantly the chances of a successful well discharge.

1. INTRODUCTION

In order to evaluate the potential of a production well, it is imperative to discharge it. Usually, highly two phase wells or wells drilled in vapor-dominated reservoir are not difficult to discharge. Wells of this kind usually develop WHP and have hotter water column at wellbore. Liquid dominated wells, however, seldom develop WHP and cold water column stands above the major permeable zone. Initiating discharge on these wells is impossible unless they are induced. Thus, additional energy must be put into the cold water column inside the casing of these wells to convert it into a two-phase column and allow pressure to build-up.

Several methods have been tried at PNOC-EDC fields to initiate well discharge. These are:

a. Air (or gas) Compression

b. Gas Lifting

c. Well-toWell Two-Phase Injection

The air compression method raises the energy in the liquid column by conductive heating at the deeper elevation to which the water is depressed and by developing enough potential energy from the stored energy in the compressed gas. Releasing the pressure by sudden opening of the wellhead valve converts some of the potential energy into kinetic energy of the liquid as it moves up the wellbore. When sufficient volume of water is heated above the BPD curve for zero wellhead pressure during this period, the sudden opening of the wellhead valve will cause flashing in the wellbore and this will initiate an upflow discharge. The concerns raised in using method are the high risk for thermal shock in the casing due to sudden heating, and accumulation of debris inside the wellbore due to rapid inflow of fluids, especially if more than one attempt is required.

The second method of initiating well discharge is gas lifting. This method relies mainly on mechanical unloading of the cold liquid column by artificially increasing the buoyancy of the water through the formation of a two-phase gas and water mixture without adding thermal energy. Using a lower gas rate during the early stage of the procedure ensures slow heating of the upper casing thus avoiding rapid thermal expansion and casing joints failure. The method is however very expensive due to the use of a large volume of liquid nitrogen and in most cases, has a low chance of successfully discharging the well.

The most commonly used method of initiating well discharge in PNOC-EDC fields is the well-to-well two-phase injection. This method has the advantage of heating the the upper casing and directly heating the cold liquid column by mixing with the hot injected water. The initial application of this method involves the use of a common two-inch (2in) line connected to the wing valve of both the induced (receiver) and inducing (source) well (Figure 1).

Prior to the injection, the source well, which should be discharging, is throttled to maximum WHP. It may either be discharging to silencer or cut-in to system. Injection usually lasts for about two (2) days. During this time, the pressure of both the source and receiving well have eventually equalized. Though initiating a discharge by injecting two-phase fluid through a 2in line works in many cases, it also has some disadvantages:

1. Longer injection time is required. This not only delays the actual discharge attempt but can also cause loss in revenue especially when the source well is on-line to system and is throttled or even cut-out for quite some time during the injection period.

2. In most cases, it takes several attempts before the induced well finally discharges. The most probable cause of this is that in some instances, the induced well was cooled down due to collapse of the injected two-phase fluid after several days of injection through a 2in line.

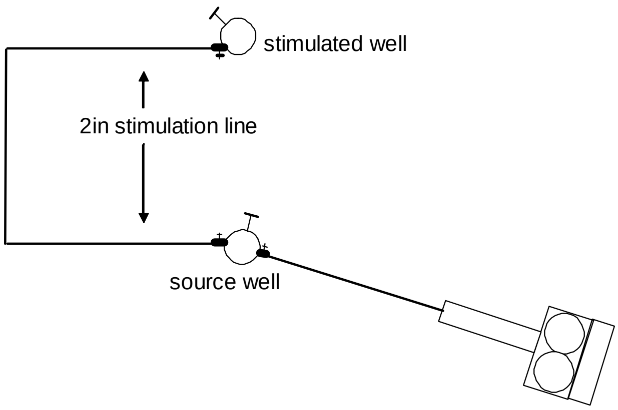

Figure 1a: Schematic diagram of a 2-in injection line set-up

Figure 1b: Picture of a well with 2-in injection line

2. METHODOLOGY

The existing well-to-well two-phase injection set-up was modified by substituting the 2in injection line with a 10in line. It was surmised that the problems encountered while using the 2in line during injection will be rectified by the use of the 10in line.

Originally, the idea of using 10in line for two-phase injection was thought of sometime in 1997 at the onset of power plant commissioning of Mahanagdong-B. It was at this time that fast track well discharges were conducted to test the different output of the wells prior to the plant commissioning. One of the well to be tested, MG31D, was induced several times by two-phase injection from MG30D using 2in line but the well failed to discharge after each attempt. It was then decided to install a 10in line as replacement for the 2in.

The well-to-well two-phase injection set-up using the 10in line is illustrated in Figure 2. The 10in line is attached to two-phase branchline stub-ins of both the source and receiving wells. Both ends of the 10in line have a valve for control of two-phase fluid flow during actual injection activities.

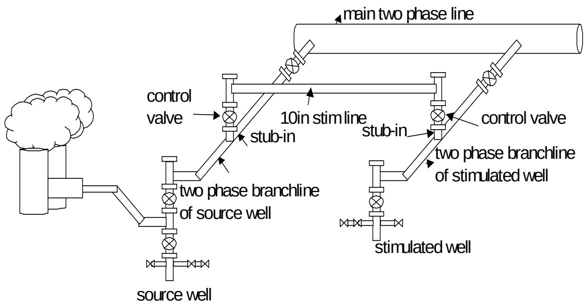

Figure 2: Schematic diagram of a 10-in injection line set-up

The source well of the two-phase injection activity is either discharged to silencer via the side valve at throttled condition or bled-off to mini silencers via the wing valve or on-line to system at throttled condition. This is to maintain a two-phase condition on the source well. It is wise to throttle the source well to maximum WHP. By doing this, the two-phase fluid that will be injected to the receiving well will have a higher saturation temperature equivalent. And although not so significant, this can also add some potential energy that will help the receiving well to discharge successfully. The master valve of the receiving well is then opened as well as the control valve of the 10in injection line along the receiving well side. At the start of the two-phase injection activity, the control valve of the 10in line along the source well side is opened. Two-phase injection will take place while the source well is continuously discharging to silencer and will terminate after the wellhead pressure of both the source and receiving well is about the same.

3. RESULTS

The modified well-to-well two-phase injection set-up was mostly used in some wells of Mahanagdong. The Mahanagdong Geothermal Field is situated within the Leyte Geothermal Production Field, southeast of the Tongonan Geothermal Field (Figure 3).

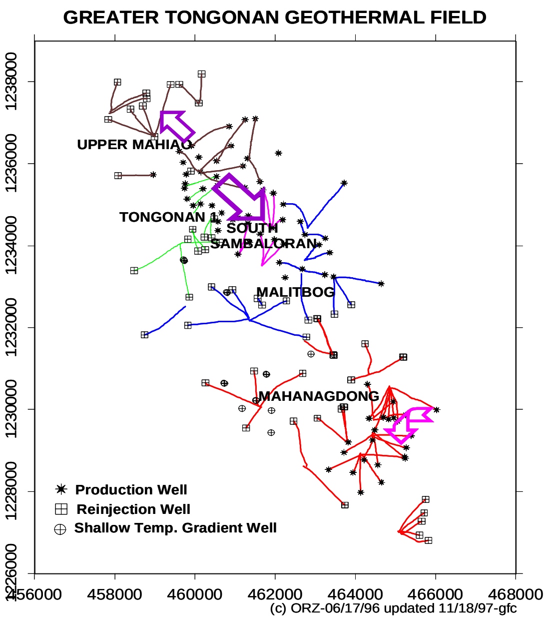

Figure 3: Location Map of Greater Tongonan Geothermal Field

Mahanagdong has a liquid dominated reservoir with a total of 48 wells drilled at elevations of about 600 mASL to about 900 mASL. Wells in the area have low water level at wellbore (~200 mASL) and seldom develop either two phase or gas pressure. These are the reasons why most Mahanagdong wells do not discharge unless induced.

Using the bigger injection line, the time it takes for the wellhead pressure of both the source and receiving well to equalize has greatly reduced. Table 1 compares the duration of the well-to-well two-phase injection activity of both the 2in and 10in lines.

Source Well	Receiving Well	WHP (MPag)	Duration of Inj.	Result of Discharge	Inj. Line Dia.	Date
MG30D	MG31D	3.0	50 mins	Successful	10in	Jul 1997
MG19	MG32D	2.15	55 mins	Successful	10in	Aug 1998
MG19	MG32D	--	2 days	Not Successful	2in	Jul 1998
MG23D	MG32D	--	2 days	Not Successful	2in	Jul 1998
MG32D	MG23D	2.0	3 days	Not Successful	2in	Jan 1999
MG19	MG33D	2.1	1 hr & 20 mins	Successful	10in	Nov 1999
MG19	MG32D	2.0	40 mins	Successful	10in	Nov 1999

Table 1: Tabulation of some wells in Mahanagdong that are induced by two-phase injection using 10in and 2in lines

It is clear from the tabulation that for the same source and receiving wells, it would only take about 55 minutes to complete a two-phase injection activity using a 10in line, as against two days or more using a 2in line. This is for the case of MG19 as the source well and MG32D as the receiving well. It was also observed that using a 10in line, more successful discharges are initiated. In fact wells that failed to discharge using 2in line were successfully discharged when induced using a 10in line.

Table 1 is just a tabulation of some of the wells that underwent well-to-well two-phase injection. It is important to note that not all two-phase injections using 2in line are unsuccessful and not all using 10in lines have resulted to a successful discharge.

However, the big advantage of the 10in line over the 2in after an unsuccessful discharge attempt is that the well can be induced again and discharge attempt can be conducted on that same day while the receiving well's wellbore condition is still significantly heated-up from previous injection activity.

4. DISCUSSION

Inducing a well to discharge using two-phase injection mainly relies on the added thermal energy generated when the two-phase fluid heats up the upper casing and the existing cool water column of the receiving well, more than the potential energy provided by the additional head.

Figure 4 shows a typical temperature and pressure profile of a receiving well while being induced by two-phase fluid via a 2in line. Temperature at the topmost part is that of the injected two phase fluid as it enters the wellbore, and is approximately the saturation temperature equivalent of the source well's discharging WHP.

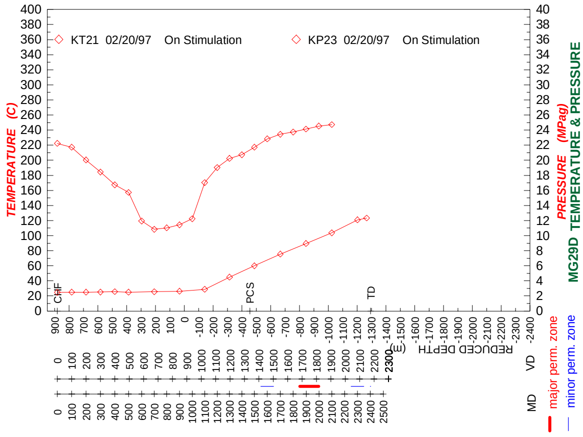

Figure 4: Sample of a temperature and pressure profile of a well (MG29D) being induced by well-to well two-phase injection

The temperature will then decline slightly due to loss of heat as injected two-phase fluid progresses downward the cold casing. The lowest temperature value while on injection is at the point where the two-phase fluid mixes with the existing cool water column.

But, although this region is the minimum temperature during injection, this is considerably higher than the original temperature value at this depth when injection has not yet started (Figure 5).

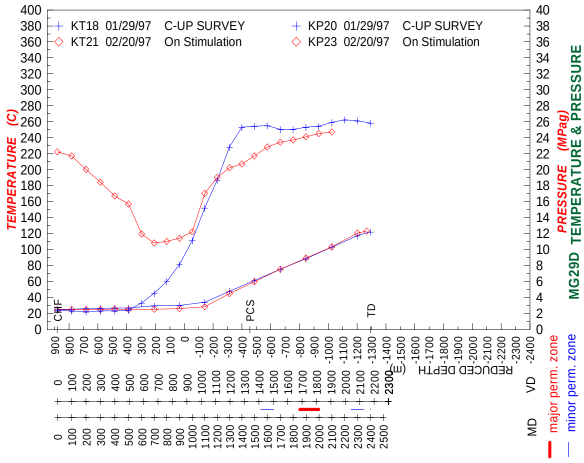

Figure 5: Comparison of MG29D temperature at water level before and during two-phase injection

There are also instances when the downhole temperature condition of the well to be induced is higher than that of the injected two-phase fluid (Figures 6 and 7). At this condition, it is crucial that two-phase injection should not be prolonged.

Otherwise, the injected fluid would cool down further the liquid column of the receiving well. And even if the injected fluid has a temperature above that of the receiving well, liquid column can still be cooled down when the injected fluid eventually condensed as it is allowed to settle on the wellbore of the receiving well for long (Figures 8 and 9). The decline in temperature is usually significant from the water level down until near the major permeable zone for induced wells with high permeability or until further down the well bore for low permeability wells.

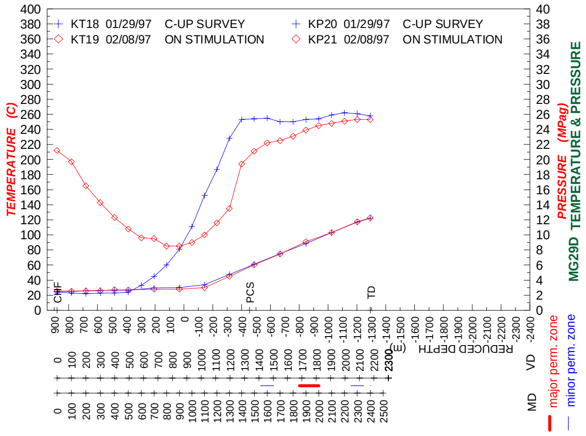

Figure 6: MG29D profile after 3-days of two-phase injection. Two-phase injection was continued for 2-days more after this survey with unsuccessful discharge.

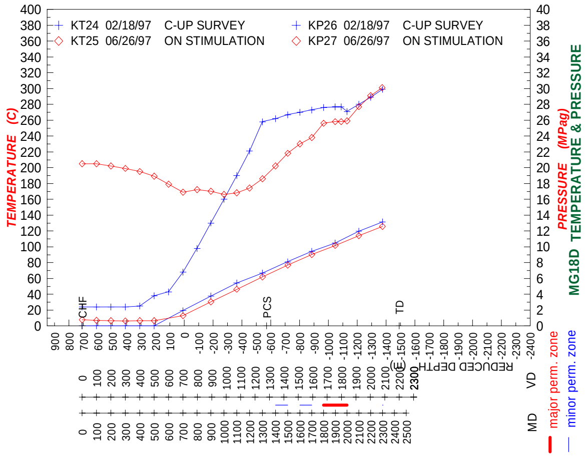

Figure 7: MG18D profile after 3-months of two-phase injection. Injection was prolonged as the well was least prioritized during commissioning activities of another plant. Discharge was not successful.

This cooling effect on the liquid column is a major reason why most two-phase fluid injection via 2in line could not set off a successful discharge. Not even the much heated-up upper section of the induced well's casing due to extended injection can improve the chance.

Because the use of a 10in line has reduced the two-phase injection activity, success rate in starting a discharge using this set-up has also improved. It is only unfortunate that there is no downhole survey available during injection using 10in line. It takes much longer to complete a typical downhole survey (~4 hrs) than to induce a well using two-phase injection via a 10in line.

To date, most of the pipeline set-up in Mahanagdong has a 10in stimulation line installed at the two-phase branchline stub-in (Figures 10 to 12).

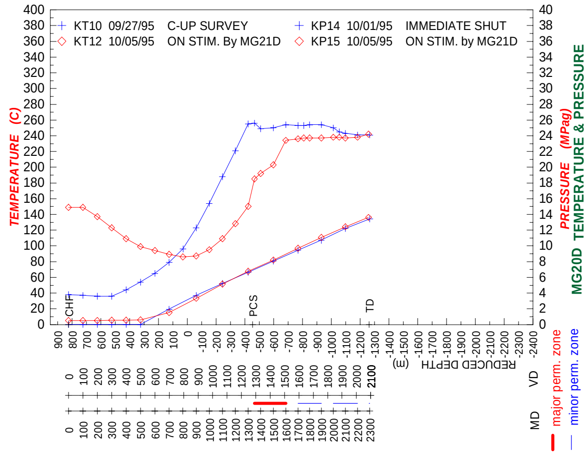

Figure 8: MG20D profile after 3-days of two-phase injection. Discharge was not successful.

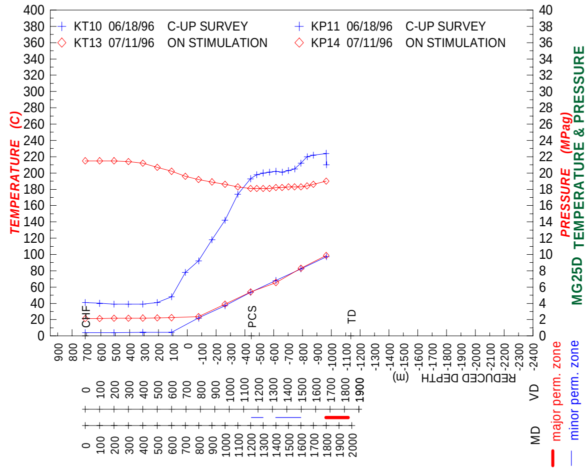

Figure 9: MG25D profile after 3-days of two-phase injection. Injection was continued for 3 more days after this survey. Discharge was not successful.

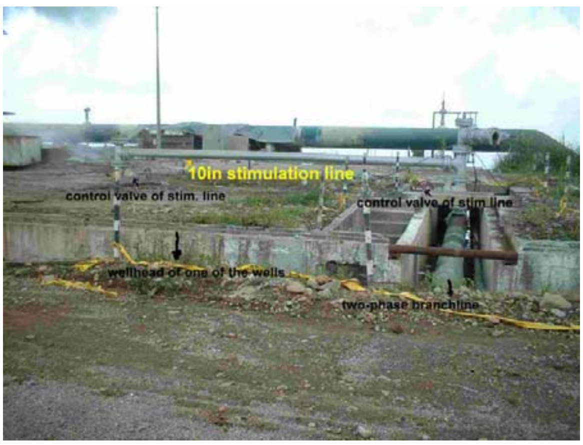

Figure 10: Sample of 10in injection line Set-up.

Figure 11: Another View of the set-up.

Figure 12: The same set-up showing the side going to the other well

5. ESTIMATED COST OF TWO-PHASE INJECTION

Summarize in Table 2 are the comparative first cost of pipe material for a 2in and 10in line used in well-to-well two-phase injection. This is based on a typical straight-line distance of ~10m between the source and receiving well's two-phase branchline. .

Inj. Line Diameter	No. of Pipe Lengths Needed (@6m/length)	Cost per Pipe Length (in USD)	Total Cost (in USD)
2in	2	89.00	178.00
10in	2	2,678.00	5,356.00

Table 2: Comparative first cost of using a 10in and 2in lines for two-phase injection.

The cost of using a 10in diameter line as injection line is significantly higher compared to that of a 2in diameter line. However, this is offset by the downtime of the source well used in the two-phase injection. As shown in Table 1, it would take ~2 days to induced well discharge if a 2in injection line is used, as compared to ~2 hrs if using a 10in injection line. Considering this time frame, equivalent loss generation cost (@ USD 0.06/kWh) as a result of the source well's downtime, with average output of 5 MWe, is shown in Table 3.

Inj. Line Diameter	Source Well Downtime Period (in hrs)	Loss in Generation (in kWh)	Equivalent Cost (in USD)
2in	48	240,000	14,400.00
10in	2	10,000	600.00

Table 3: Loss generation cost equivalent to source well's downtime period.

6. CONCLUSION

The well-to-well two-phase injection using 2in line has the following limitations:

1. Longer injection period (2 days or more) before the WHP of both the source and receiving well eventually equalized.

2. Cooling of the water column of the receiving well, either due to condensation of the injected fluid and/or the injected fluid has a lower temperature than the existing liquid column.

Because of the enumerated limitations, lesser chance of starting a discharge is observed.

The duration of two-phase injection activity through a 10in line has reduced to an average of 60 mins. Cooling during injection was reduced or even eliminated. Well induced using this method almost always discharge successfully.

The following factors must be considered prior to inducing a well:

1. Maximum WHP of the source well

2. Existing downhole temperature condition of the well to be stimulated

If the corresponding saturated temperature of the source well's WHP is much lower than the receiving well's liquid column, then other methods of initiating a discharge must be considered. Pursuing well-to-well two-phase injection, especially with 2in line, will only cool the liquid column of the receiving well.

7. ACKNOWLEDGEMENT

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8. REFERENCES

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