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A METHOD FOR ESTIMATING CAPACITY INCREASES FROM ACIDIZING MUD-DAMAGED REINJECTION WELLS

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Abstract

Acid stimulation of mud damaged wells involves a great deal of time and resources. In fasttrack , time constrained geothermal development such as that currently undertaken by PNOC-Energy Development Corp. (PNOC-EDC) , every capacity gained fiom acidizing is an essential input to the overall development plan and strategy. Thus, aside fiom identification of candidate wells for acidizing, there is a need to predict possible gains that would result fiom such undertaking. This paper presents a method for evaluating the capacity increases to be expected by acidizing mud damaged reinjection wells.

The method is based on including a zero data point in the injectivity test plot. An offset between the extrapolated injectivity line and the zero flow pressure indicates a "skin pressure" or "flow initiation pressure" due to viscous mud. The pressure difference (ΔP) is the available pressure that can be removed by acid stimulation. This can then be used to determine an estimate of the reinjection capacity increase from acidizing. This method however is not applicable to high permeability wells suffering skin damage caused by mineral deposition or cement slugging.

The method gives good agreement with actual results for wells MN1, 5R7D and 4R6D.

1.0 INTRODUCTION

The mechanism by which capacity increases are obtained by acidizing mud damaged reinjection wells is different to our initial expectations. The skin has been seen as an area of lower permeability adjacent to the wellbore which adds an extra hydraulic resistance to flow If this were true then removing the skin with acid would give a higher injectivity index. In fact, what happens is that there is a drop in " reservoir pressure'' shown as an offset of the injectivity plots for pre-acid and post-acid tests. The injectivity index remains the same (Figure 1).

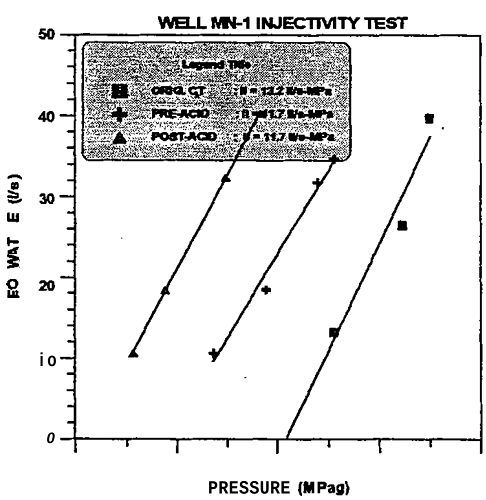

Figure 1

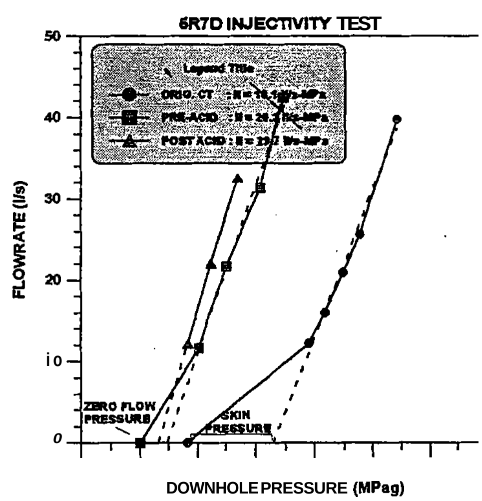

Figure 2

However, pumping a few thousand litres of acid cannot actually alter the true reservoir static pressure of the well as this is governed by the whole reservoir volume surrounding the well, not just the region adjacent to the well. There must be a "pseudo-pressure" due to the mud prior to acidizing which alters the flow versus pressure characteristic of the well. Including the zero flow pressure in the injectivity plot makes this clear. (Figure 2.)

The viscous drilling mud exhibits non-Newtonian behaviour. When pumping starts, the mud forms a seal which allows no flow. When the pressure reaches a critical level the water forces a path through the mud and once this flow-path is open the mud does not offer additional resistance to flow as the pump rate increases. This means that the slope of the flow versus pressure plot, the injectivity index, is determined solely by the permeability of the formation with no effect from the mud. A fixed pressure is required to keep the flow-path open through the mud, but this is independent of flowrate. Acidizing removes the mud and the "skin pressure" required to initiate flow.

2.0 METHOD FOR PREDICTING CAPACITY GAINS FROM ACIDIZING

The injectivity plot should be drawn together with the zero flow pressure. The zero flow pressure for a tight well is probably best estimated by using the pressure at the end of the pressure fall-off (PFO) test, when the well has been shut for 6-8 hours. For a more permeable well the one day shut pressure survey should be a good estimate. For tight wells with no PFO or 1 DS survey the static pressure can take days or weeks to stabilize, so this would give an apparently bigger offset between the extrapolated injectivity line and the static pressure than the correct zero flow pressure.

Extrapolating the injectivity plot to zero flow gives an intercept with the pressure axis which have been called the "skin pressure". The offset between the zero-flow pressure and this skin pressure is the ΔP (skin) required to keep open the flow-path through the mud

To estimate the capacity a new injectivity line with the same slope is drawn through the zero-flow point and used for a second RICAP calculation. The difference between the original capacity estimate and this new estimate gives the gain to be expected from removing the mud with acid

For tight wells the flow and hence frictional pressure drop is small, so a reasonable quick estimate can be obtained from multiplying the injectivity index by ΔP *(skin)* i.e.

$$\text{capacity gain} = II * (P_{skin} - P_{zeroflow}) \qquad \text{(Equation 1)}$$

3.0 COMPARISON WITH ACTUAL DATA

The method was applied to a number of mud damaged wells which were programmed for acid stimulation. The estimated capacity gain computed from the method earlier discussed were compared to the actual gain obtained after the acid job. It can be seen that there is good agreement between the estimated capacity gain and that actually obtained Table 1 shows the tabulated results.

W4R6D, a low permeability tight well, was acid stimulated to enhance its fluid acceptance. Re-acid completion tests yielded an injectivity index of 10.0 l/s-MPa which is similar to its original value. The pre-acid injectivity test plot however, showed a higher downhole pressure response compared to its original completion tests data. This may have been caused by the caking/hardening of the mud (HVM) left in hole during drilling, resulting to further damage. Estimated capacity gain from the original and pre-acid completion tests obtained an increase of 13 l/s and 7 l/s respectively. Post-acid completion tests obtained an injectivity index of 12 l/s-MPa and a notable shift in downhole pressures back to the original completion

***Table 1** : Estimated Capacity Gain and Actual Gain*

Well Test	Injectivity Index (l/s-MPa)	P(skin) (MPag)	P(zero flow) (MPag)	DP(skin) (MPa)	Est. Capacity Gain (l/s)	Actual Gain (l/s)
4R6D CT	10.6	15.0	13.8	1.2	13	--
Pre-acid	10.0	16.2	15.5	0.7	7	15
MN-1 CT	13.2	16.2	14.2	2.0	26	--
Pre-acid	11.7	13.8	11.7	2.1	25	20
5R7D CT	18.1	14.3	12.8	1.5	27	--
Pre-acid	20.3	12.5	12.0	0.5	10	12

tests zero flow pressure. Computation of post-acid reinjection capacity revealed a gain of about 15 l/s which is close to the estimated gain.

MN-1, a low permeability well, likewise showed the same response. The well had a pre-acid injectivity index of **13.2 l/s-MPa** (Fig. **3).** The extrapolated injectivity lines of the original and pre-acidizing revealed an **offset** of **2.0MPag** and 2.1 MPag respectively with respect to the zero flow pressure **data.** The **index** however was still close to the pre-acid value. It is important **to** note **that** even before acidizing, **an** improvement in downhole pressure was observed. The well may have **been** stimulated **by** the extended pumping prior **to** the pre-acid **completion** tests. Post-acid stimulation results show improvement in downhole pressure **with** the injectivity line **shifting** back to the zero flow pressure. The estimated gain of 20 l/s computed based **on** the pre-acid data is close to ***the*** actual capacity calculated after the stimulation.

5R7D **is a** moderate permeability well acidized to remove mud damage and at the same time clear the well from possible scale and mineral deposits. **This** well was **used as** a reinjection well during discharge tests and **silica** inhibition expriments at the Malitbog sector of the Leyte Geothermal Field **This** well has undergone pressure drawdown **as** a result of the Tongonan I geothermal field exploitation. This is evident in the pre-acid injectivity test which showed a lower downhole pressure during pumping although the computed index **is similar** to the original **index.** A capacity **gain** of 12 l/s (Fig.4) was obtained which is close **to** the **estimated** gain computed using the suggested method.

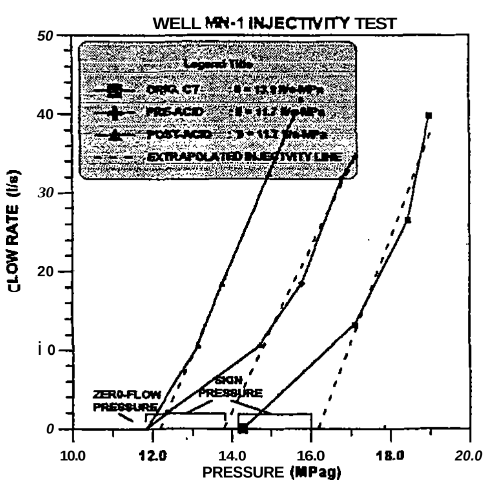

Figure 3

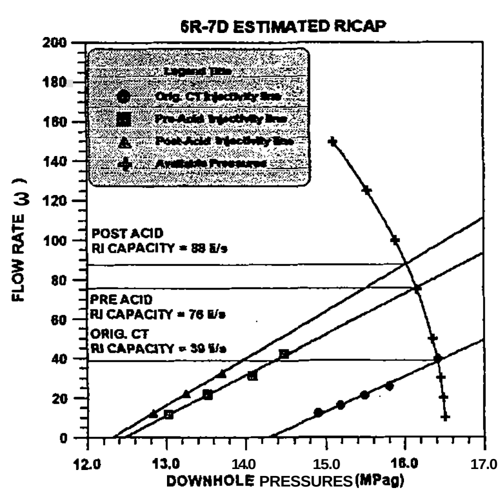

Figure 4

The same method was applied to high permeability, mud and cement damaged wells MG-7RD (Fig. *5)* and 110D. However, results yielded increases in injectivity indices aside from the shift in the injectivity line. Both wells have high **permeability** zones on the upper section which were cement plugged due to hole problems encountered **during** drilling. The plugged zones of both wells had been drilled with total loss circulation (TLC). These zones may have been cleared during stimulation, resulting to an actual gain far higher than what was estimated (Fig. **6).** In the case of well **MG-7RD,** the 98.6 li/-s-MPa increase in **injectivity** index resulted **to** a ***gain*** of about **261 l/s as** compared to the pre-acid **capacity.**

Table 2 :Injectivity Test Results of High Permeability, Mud and Cement Damaged Wells

Well	Type	Injectivity Index (li/s-MPa)		
		Orig. CT	Re-acid	Post acid
MG-7RD	Reinjection	**17.0**	15.4	114
110D	**Production**	42.0	**77.2**	**270.5**

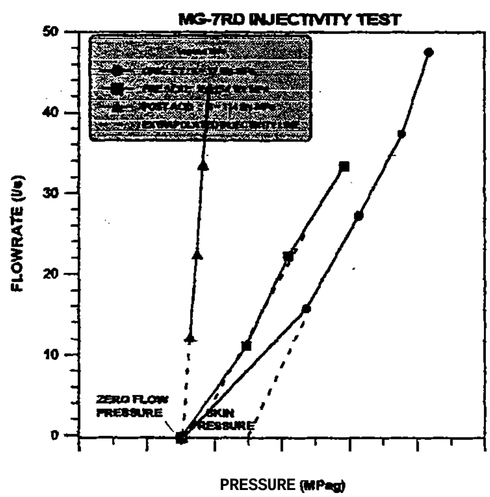

Figure *5*

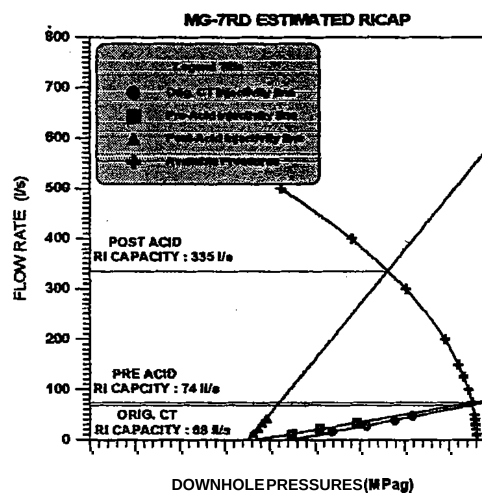

Figure *6*

4.0 APPLICATIONS

The method presented *can* basically be applied to wells which have **been mud** damaged during drilling. It **has** various **useful** applications in the field of geothermal development. **These *can*** be **summarized as** follows:

- Knowing the estimated **gain** before undergoing acid stimulation could be a very valuable tool in decision **making** with regards to the overall development plan **and** strategy of the field ***As*** every gain in capacity counts, any means of increasing capacity through the fastest and ***cost*** effective **means** would be most desirable.

- Management decisions on any crucial and costly undertaking such **as** acidizing requires data and information on its economic viability. **This** method could provide the quantitative **gain** that would be expected and prevent heavy financial losses that would result **from lack *of*** much needed **data.**

- The method can also be used side by side with the skin factor computation to identify mud-damaged wells.

- In cases where the pressure response during fall-off tests are affected by thermal and other nuisance effects where the data are unreliable and no analysis can be made, this method can be used as alternative in identifying mud damaged wells.

5.0 LIMITATIONS

This method is however reliable only on mud damaged wells as wells with damage of different nature other than mud show different response. For cement damaged high permeability wells, the above mechanism may not be valid Well 110D and MG-7RD behaved quite differently. In both cases there was an apparent increase in the injectivity indices which may have been due to the opening of the cement plugged permeable zones. Opening of these zones have very significant contribution to the wells overall permeability.

The method presented may also not be appropriate for reinjection wells suffering from silica deposition, but since the drop in capacity has already been established, the expected gain from acidizing could already be predicted.

6.0 CONCLUSIONS

The estimation of capacity increase using the method discussed showed a reasonable agreement with the actual values obtained after the acid stimulationjob of wells 4R6D, MN-1 and 5R7D. However, this method is only applicable to wells damaged solely by drilling mud. Wells with damage caused other than mud such as cement and mineral deposition show different response when stimulated as observed from the results of wells 110D and MG-7RD. The opening of cement plugged, highly permeable zones resulted to an increase in injectivity index aside from improvement in downhole pressure response to pumping.

In applying the method, certain procedures should be followed in order to come up with a reasonable estimate. These can be summarized as follows:

- The zero-flow pressure point should be included on the plot of the injectivity test results, as this will enable mud damaged wells to be identified.

- Wells with positive WHP during injectivity test should undergo a single-rate PFO rather than two-rate. The pressure at the end of the PFO can then be used as zero-flow data point.

- Similarly, for pre-acid testing, a zero flow pressure survey is recommended to obtain the zero-flow pressure. It is possible that extended pumping may have already washed away much of the mud

The expected capacity increase from acidizing can then be computed by calculating the capacity with the RICAP program or spreadsheet using first the original injectivity data and secondly the injectivity data with the pressure reduced by [P(skin)-P(zero-flow)] for each data point. An approximate estimate for lower flows is given by the equation [1.1. * (P(skin)-P(zero-flow)].

This method should be valid for typical reinjection wells.

Other factors such as drilling losses, total volume of mud loss, cement plugs within the open hole, and transmissivity (Kh) and skin factor calculated from transient pressure analysis should also be taken into account, together with output data if available. Cement damaged, high permeability wells should be judged on these criteria.

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