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INJECTIVITY TESTING FOR VAPOUR DOMINATED FEED ZONES

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SUMMARY - Wells with vapor dominated feed zones yield abnormal pressure data. This is caused by the condensation of vapor during water injection. A revised injectivity test procedure currently applied by PNOC at the Leyte Geothermal Power Project has improved the injectivity test results.

1. INTRODUCTION

Injectivity testing is one of the salient parts of the completion test activity of a well. During this test, the amount of brine that can be accepted by a well is indirectly determined and the extent of a well's permeability is also estimated.

The test makes use of pressure recorders which are set below the main zone for single feed wells or between two main zones (or at pressure control point) for wells having multiple feed zones. Water is pumped continuously for the whole test period with rates normally programmed at increasing trend. In PNOC, a time interval of two hours is standard for each pump rate, and the bottomhole pressure are expected to stabilize by then.

The slope (determined by linear regression) of the plot of the stabilized representative pressure data at each flowrate versus flowrate is termed **Injectivity Index** in units of li/s-MPa . The injection capacity of a well is determined by the intersection of this injectivity line and a plot of available head versus flowrate. It is important for downhole pressure data during injectivity test to have fully stabilized at each rate in order to obtain an Index value that truly represents that of the well. Figure 1 shows stabilized pressure data with respect to flowrate.

Figure 1: Pressure versus Time plot of W416

The Injectivity testing procedure described earlier does not seem very successful on vapor dominated wells. Wells 415, and 413 are examples of vapor dominated wells situated at the Upper Mahiao sector of the Tongonan field. Their pressure vs time plots are shown on Figs 2 and 3. Both plots depict a similar unstabilized pressure trend vs time. Except at the minimum rate, the pressure values continuously decrease for the whole test period allotted for

Figure 2: Pressure versus Time Plot of W413

Figure 3: Pressure versus Time Plot of W415

each rate. This is attributed to the condensation of steam during injection at high pump rates. The index values

calculated from these data are then considered unreliable as pressure values for each rate failed to reach stability with respect to time. The injectivity index obtained is an over-estimate of the permeability of the well. In extreme cases a negative index may be obtained as the pressure at high pump rates is lower than at lesser flowrates. Also, no valid kh and skin values are obtained during pressure fall-off test as change in pressure vs change in time data follow a strange curve and can not be matched with the Ramey type curve (Fig. 4, and Fig. 5).

Figure 4: Log-Log Plot of W413

Figure 5: Log-Log Plot of W415

2. METHODOLOGY

To be able to obtain reasonable pressure data from vapor dominated feed wells, it is necessary to create a single phase liquid region close to the wellbore during injectivity test. When this is attained, the pressure will no longer be affected by the condensation of steam during cold injection.

The method used to accomplish this aim is by conducting the injectivity testing at two flowrate trends (increasing and decreasing). The steam is expected to condense during the increasing trend stage and data obtained from decreasing flowrate trend will be considered in calculating the injectivity index.

3. RESULTS

The method has been applied to recently-drilled wells situated in the Upper Mahiao sector of the Tongonan field and to a well in the Malitbog sector, for wells found on this

area are believed to be highly two-phase. For vapor dominated wells, namely 401 and 414D, the injectivity index values that resulted from decreasing flowrate trend are lower than what are obtained at increasing flowrates (Table 1). The index value yielded from decreasing rates for each well is a more reasonable representation of the respective wells. This is because the Pressure vs Time plot at declining rate gave a more stable pressure profile (Figs. 6, 7, 8, 9 and 10) and the corresponding Rate vs Pressure plot show a better linear correlation as compared to that obtained at increasing rate. This means that index values obtained from increasing rates for vapor dominated wells are over-estimates.

TABLE 1-Injectivity Index Values of 401 & 414

Rate	INJECTIVITY INDEX li/s-MPa			
	W401		W414	
	KP-33	KP-34	KP-09	KP-10
decreasing	39.8	42.9	35	33
increasing	64.5	78.0	41	43.8

Figure 6: W401 Pressure versus Time Plot

Figure 7: W401 Injectivity Plot at Increasing Rate

Figure 8: W401 Injectivity Plot at Decreasing Rate

Figure 9: W414 Pressure versus Time Plot

Figure 10: W414 Injectivity Plot

For liquid dominated two phase zones, the index values obtained at increasing and decreasing rates are comparable

Table 2: W416 Injectivity Index Values

W416D	INJECTIVITY INDEX li/s-MPa	
	KP-1	KP-2
INCREASING	26.0	25.2
DECREASING	24.5	25.7

(Table 2). For very permeable wells of this type, the Pressure vs Time plot shows a stable profile at both flowrate trends (Fig. 11).

Figure 11: Pressure versus Time Plot of W4R9D

3. DISCUSSION

The fact that the decreasing pressure trend at higher flowrates observed during injection of water into vapor dominated feed zones is remedied by the suggested Injectivity test method and better injectivity test plots are thus obtained suggests that the results from the method can be considered more reasonable. Since data points at decreasing rate are usually considered, a more reasonable result could have been produced if pressure at these rates had fully stabilized. It has been observed that pressure at declining flowrate takes more time to stabilize than at increasing rate. Also, the method seems to be effective in dealing with vapor condensation only during injectivity tests but not during Pressure Fall-Off tests. PFO log-log plots of wells 414 and 401 show a non-standard curve and appear to have been effected by vapor condensation.

Problems regarding vapor dominated feed zones could also be minimised by the following revisions to the injectivity test procedures:

1. Pumping at maximum rate for a period equivalent to the time usually consumed for a set of flowrate trend (6-8 hours), then pump at decreasing rate. The same procedure would also be followed for PFO test.
2. The period to be covered by each rate during water injection should be extended.

The preceding discussions are solely for wells with vapor dominated feed zones. Wells of this characteristic are usually identified by the following methods:

- (a) The downflow temperature from the vapor dominated zone recorded during waterloss surveys is above 200°C and the well head pressure during early completion test is vacuum throughout the test.
- (b) It has been observed (R.E. Tillos - personal communication) that vapor dominated zones have substantially higher vacuum readings on a wellhead gauge than is induced by pumping into a liquid dominated well.

4. CONCLUSIONS

- Injectivity and Pressure Fall-off tests following traditional methods give results from vapor dominated zones that are meaningless, as data points obtained during the tests are affected by the condensation of steam.
- This problem of vapor condensation during injection of cold water can be eliminated by creating a single phase liquid region near the wellbore. One way of doing this is by conducting injection at increasing rates first then at decreasing rates. The results obtained using this method are better than those obtained using the standard method. However, the following flaws have been observed:

(a) Data points considered in calculating the Injectivity Index value had not fully stabilized.

(b) PFO plots are still affected by the condensation of vapor.

- The following revisions of the method might eliminate the problems with injectivity tests:

(a) Pumping at highest rate for a longer time before pumping at decreasing rate.

(b) Prolonging the period of each rate during injection.

5. ACKNOWLEDGEMENT

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6. REFERENCES

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