# 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 flowrateis termed Injectivity Index in units of l/s-MPa. The injection capacity of a well is determined by the intersection of this 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.

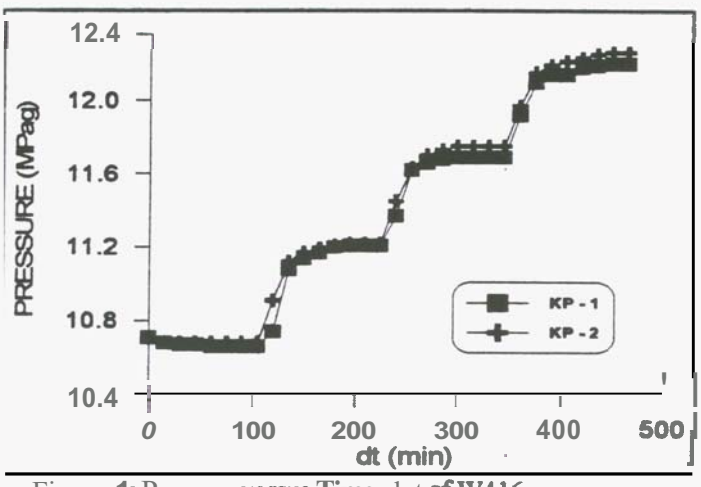



Figure 1: Pressure versus Time plot of W416

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 similarunstabilized pressure trend vs time. Except at the minimum rate, the pressure values continuously decrease for the whole test period allotted for

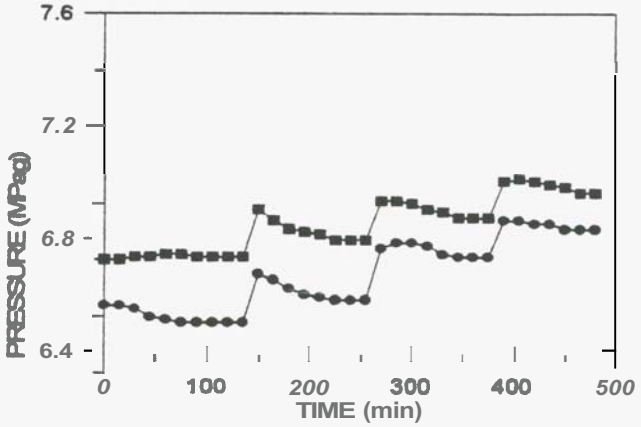



Figure 2: Pressure versus Time Plot of W413

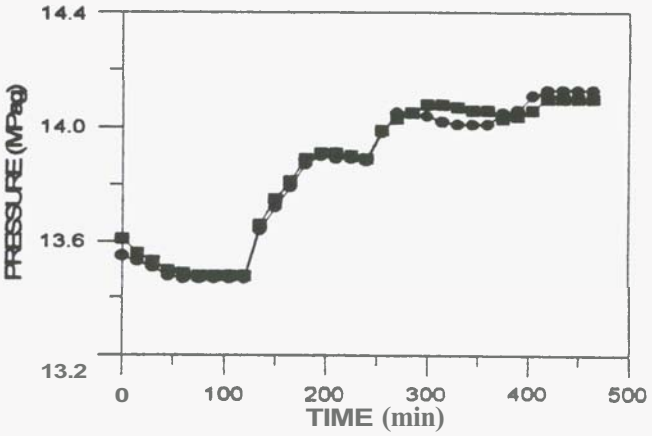



Figure 3: Pressure versus Time Plot of W415

tach 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 that 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).

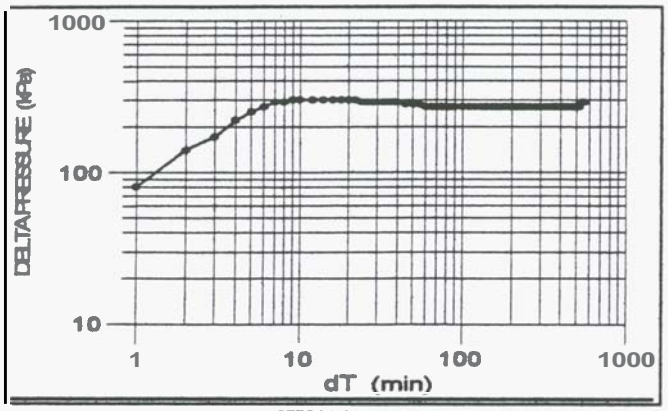



Figure 4: Log-Log Plot of W413

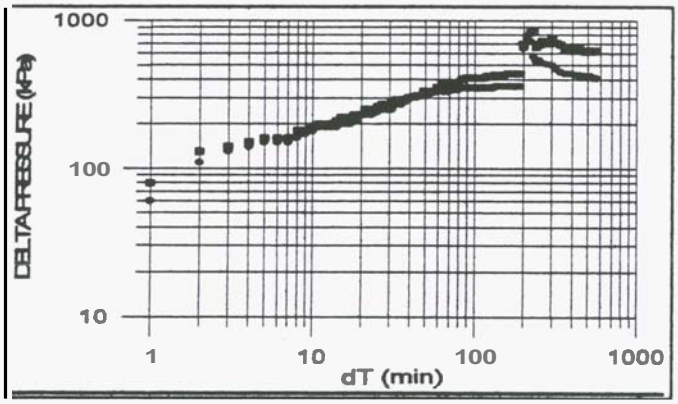



Figure 5: Log-log Plot of W415

## 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 Ressure plot show a better linear correlation as compared to tbat 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

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

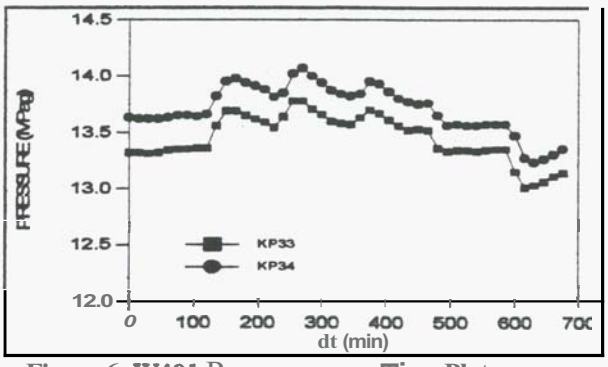



Figure 6: W401 Ressure versus Time Plot

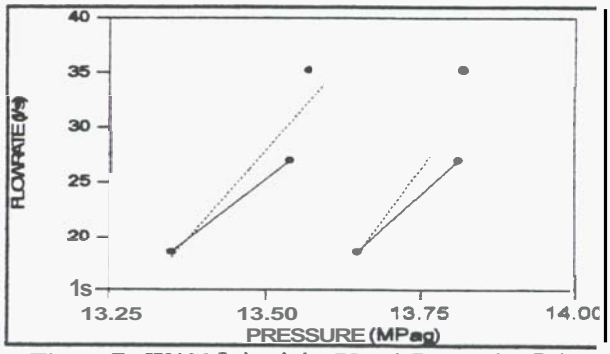
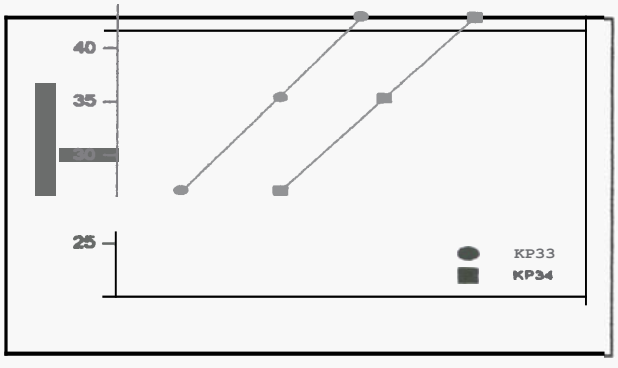



Figure 7: W401 Injectivity Plot at Increasing Rate



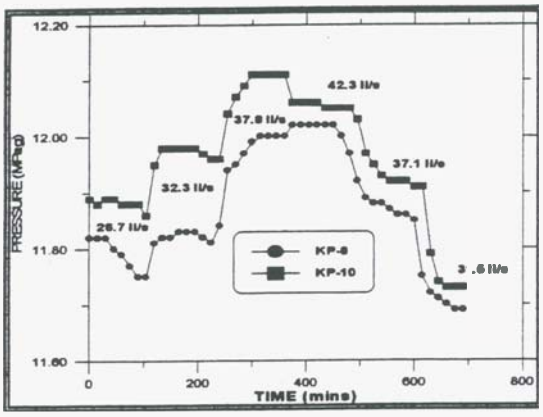



Figure 9: W414 Pressure versus Time Plot

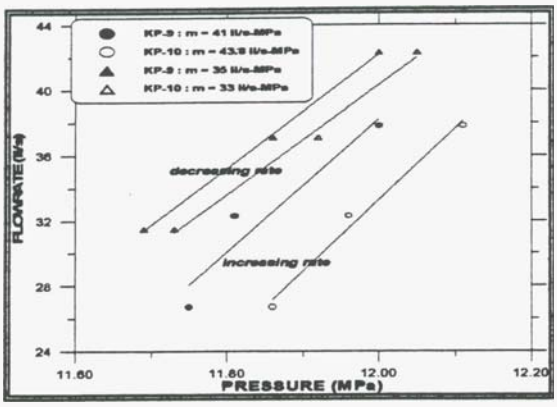



Figure 10: W414 Injectivity Plot

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 | |
|---|---|---|
| RATE | KP-I | 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).

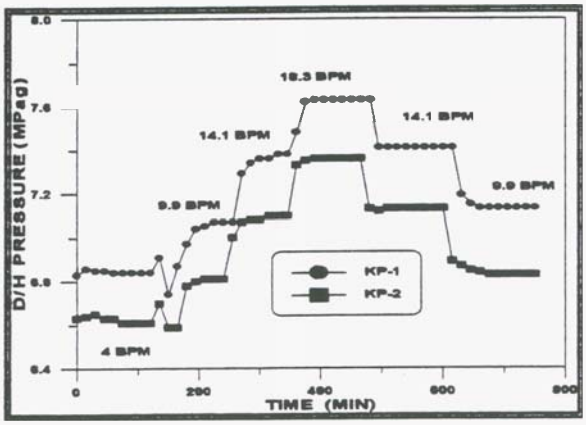



Figure 11: Pressure versus Time Plot of W4R9D

## 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 Ressure 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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