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Huff and Puff Method to Overcome Wellbore Damage

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ABSTRACT

Well WD-3 is a development well at the Karaha Bodas Geothermal Field located in Tasikmalaya, West Java. It was drilled successfully and it penetrated the reservoir zone which has a natural steam cap overlying the liquid zone. This well is interpreted to have wellbore damage attributed to the drilling fluids, especially mud, cuttings and other formation debris which may be blocking the fractures and potential feed zones. This condition led to a significant delay in temperature recovery and its chance to discharge commercially is considered small. In such a case, the Huff and Puff method, which means repeatedly discharging a well and shutting it after a significant period of time, has to be applied.

1. INTRODUCTION

Production testing is carried out on a well after the completion test, usually after several days or months of heat-up, to determine the characteristics of the well, estimate the well potential and clean the wellbore from dirt, remains of cuttings or drilling fluid. PT Pertamina Geothermal Energy (PGE) conducts production testing through flat lip and horizontal means. The flat lip test is the same as the upright, with just a change of the vertical position of the pipe lip to a horizontal one. However, in the flat lip test, two-phase fluid is flashed in the silencer. The silencer is used to muffle sound and flash two-phase geothermal fluid. The silencer is fitted with a weir box equipped with a v-notch for brine flow measurement.

However, in many cases, not all wells can easily discharge. Until very recently, many wells in the field had been drilled with mud as the drilling fluid. This is suspected to have caused severe damage in the wells causing difficulties for the wells to flow. Not discharging does not mean that the wells could not produce; these wells may have suffered damage. Such deduction could not apply especially when a well nearby with almost the same downhole characteristics was successfully tested. Hence, jumping to a conclusion has to be avoided.

This paper discusses the Huff and Puff attempts to overcome and evaluate parameters associated with wellbore damage that resulted in difficulties on discharging wells. Data from the downhole pressures and temperatures, injectivity test and production tests of the nearby wells are assessed.

2. METHODS

Prediction of wellbore damage occurrence can be seen from well completion and heat-up data. This data can illustrate the characteristics of the well. If such data is not reliable, data from nearby wells and other geosciences' information is used

2.1 Data Evaluation of Well Completion and Heating Monitoring

Table 1 shows the comparative test results based on the completion data of three wells in Karaha Bodas. Well WD-3 has shown to have the lowest injectivity index although other parameters are almost in the same range as the others. Comparison of the kh (permeability) and the injectivity data showed a reverse pattern between two parameters, with a lower injectivity index having a higher kh and vice-versa. This inconsistent pattern is considered an indication that damage to the wellbore has occurred.

In addition, supporting data from the heat-up period are assessed and shown in Figure 1. From the heat-up data, it can be seen that progress of well temperature recovery is long. The maximum temperature of 221.6˚C was recorded only 53 days after shut-in; nearby wells approached stable formation temperatures within a 30 day period. This may indicate two possibilities; i.e., the well is penetrating a relatively cold zone or a disturbance in wellbore permeability has stunted the temperature recovery.

Table 1. Comparison of Well Completion Result

Well	Well Elevation (mASL)	T (deg°C)	P (kscg)	II (lpm/ksc)	kh (md)	Skin	Total Mass T/H	Water Level (mku) |
Well WD-1	1392	258.21	47.7	1002	2.55	-2.0623	79.36	>1735 | 01-05-
Well WD-2	1445	275.81	101.35	528.2	4.08	-2.411	75.43	1636.7| 14-04-
Well WD-3	1445	250.12	65.79	358.98	3.57	-2.103	52.8	1500 | 21-06-

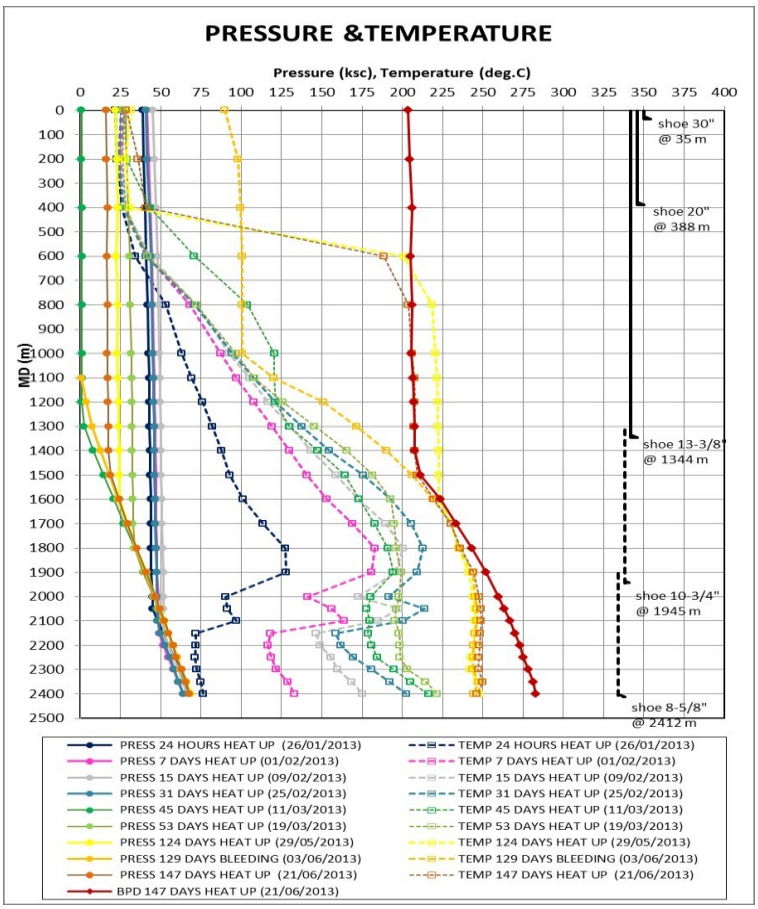


Figure 1. Pressure & Temperature Sub Surface Monitoring

2.2. Predictions of Successful Discharge

Prior to stimulation, predicting whether a well will discharge or not is carried out by determining the ratio: Af/Ac, where Af is flashing area and Ac is condensing area. The different criteria for Af/Ac to assess to the opportunity of well discharge can be seen in Table.1. This ratio involves the comparison of the area of condensation that takes place in the upper portion of the casing and the area of boiling in the well.

Table 2. Value Criteria of Af/Ac in Predicting Success Opportunity of Well Discharge (Sarmiento, 2010)

Nilai Af/Ac	Keterangan
Af/Ac < 0,70	Opportunity of Well Discharge is Small
Af/Ac > 0,85	Opportunity of Well Discharge is Big
Af/Ac = 0,70 – 0,85	Opportunity of Well Discharge is Uncertain

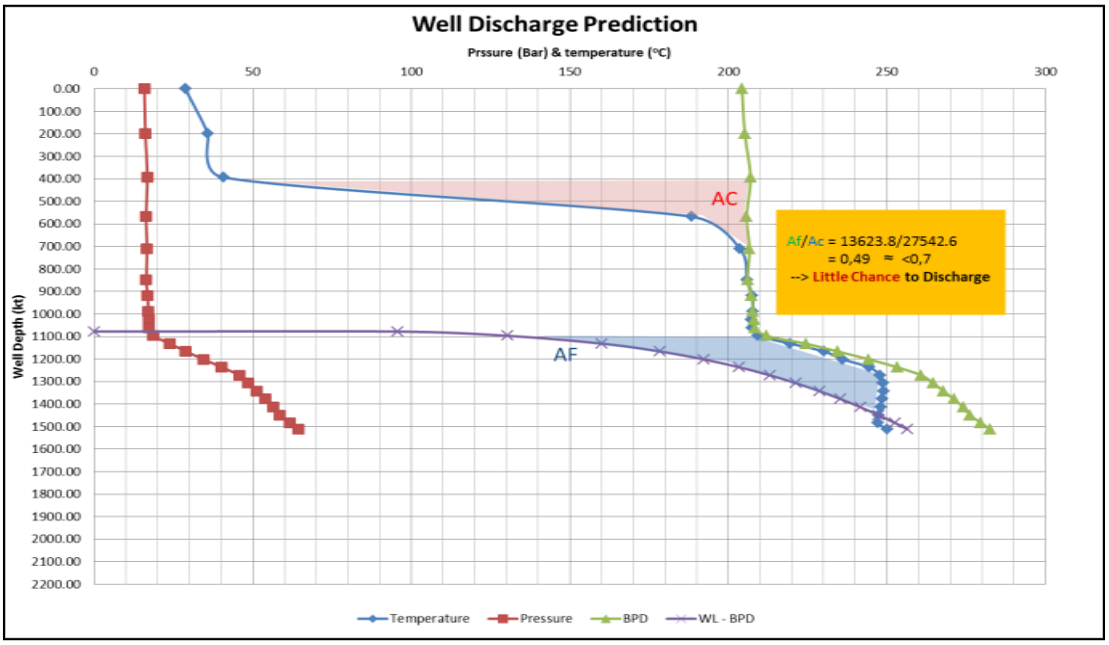


Figure 2. Well Discharge Prediction

Based on this method, the chance for the well to discharge was very small (see Figure 2).

2.3 Huff and Puff Method

As indicated earlier, the Huff and Puff method refers to discharging and shutting in the well, at most every 2-3 days and repeated many times until the well discharge has improved and has become commercially viable to produce. If the well will not discharge by itself, either an air compressor or a injecting two-phase through a nearby well is used to initiate the flow. Output is measured using the James method (James, 1988).

1. WHP -> bar.a
2. P.Lip (Pc) -> bar.a
3. D.Lip -> cm
4. P.atm -> bar
5. T.res -> ºC
6. Steam Consumption assumption -> (ton/jam) / MW

$$H = hf(T.reservoir) + (X.hfg\ (T.reservoir)$$

In the Reservoir "X" value = 0

$$H = hf\ (T.reservoir) + (0 \times hfg\ (T.reservoir)$$

$$H = hf(T.reservoir)$$

It is assumed the system is isenthalpic

$$M_{total} = \left(\frac{0.184}{H^{1.102}}\right).(A_{Lip}).(Pc^{0.96}).(3600)$$

$$X\ (drness) = \frac{(h_{f(T.reservoir)}) - h_{f(P.WHP)}}{h_{fg(P=WHP)}}$$

Russel James Equation

$$M_{steam} = M.X$$

$$M_{brine} = (M - M_{steam})$$

$$Well\ Capacity = \frac{M_{steam}}{Steam\ Consumption}$$

3. DISCUSSION AND RESULTS

When data from the completion test and heat-up period indicates the possibility of disruption (wellbore damage), the well is considered to be difficult to discharge commercially. History of the production test listed below shows the condition of the well when it was first opened.

1. 5 and 20 March 201 : bleeding well but no steam- closed
2. 27 March 2013 : well to well stimulation – no steam -closed
3. 18 and 22 April : bleeding well - no steam- closed
4. 31 May 2013 : bleeding well – no steam - closed

Results from the above six attempts indicate the well is incapable of discharging as predicted earlier. Data from nearby wells were then reviewed and their successful performance considered. A compressor was then set-up near the wellhead and air was injected into the well. This activity was repeated many times until the well indicates improvement.

5. On 30 July 2013, steam started to come out with a well head pressure (WHP) of 7.5 ksc via horizontal discharge. The discharge fluids were described to be very dirty, with wellhead pressures increasing progressively with time.
6. On 27 August 2013 started to flow using a test separator.

Table 3 shows the production test results using the test separator with WHP's as high as 16 ksc.

Table 3. Flow Rate and Dryness Based on Production Test- P sep = 9 Kscg

Date	Time	Throttle valve	WHP	$P_{Line\ 2\ Fasa}$	$P_{Separator}$	$P_{Separator}$	$P_{Upstream}$	$T_{Upstream}$	ΔPU	$T_{Weirbox}$	V-Notch	FLOWRATE			Dryness
		open (%)	(Kscg)	(Kscg)	(Kscg)	(Bara)	(Kscg)	°C	(Kscg)	°C	h (cm)	Steam (T/H)	brine (T/H)	TOTAL(T/H)	X
25 September 2013	19:00 WIB	46	16.0	9.3	9	9.7	8.8	174	0.3500	85	4.5	45.03	2.62	47.65	94.50%
15 September 2013	16:00 WIB	30	15.0	9.2	9	9.7	8.6	174	0.4000	90	5	47.99	3.34	51.33	93.49%
30 September 2013	6:00 WIB	15	14.0	9.2	9	9.7	8.44	172	0.3400	87	4.5	43.34	2.60	45.94	94.34%
23 September 2013	6:00 WIB	60	13.0	9.2	9	9.7	8.4	174	0.4400	86	4.5	50.19	2.61	52.80	95.06%
			32.0	**SHUT IN PRESSURE**											

It is evident from the table that the well is steam-dominated with a steam fraction as high as 95%. Total production at 13 ksc reaches 52.8 TPH, 50.29 TPH, and 3.34 TPH for the total mass, steam and brine flow rates respectively.

Table 4 shows the computed enthalpy based on the above discharge results. A value of 2662 kJ/kg was obtained indicating an excess enthalpy when compared to the enthalpy of the fluid corresponding to the measured reservoir temperature of 250°C.

Table 4. Enthalpy Based on Production Test- P sep = 9 Kscg

Date	Time	Throttle valve	WHP	$P_{Line\ 2\ Fasa}$	$P_{Separator}$	$P_{Separator}$	$P_{Upstream}$	ENTHALPI (kJ/kg)			
		open (%)	(Kscg)	(Kscg)	(Kscg)	(Bara)	(Kscg)	h_f	h_g	$h_{fg} = h_g - h_f$	$H = (h_f + x.h_{fg})$
25 September 2013	19:00 WIB	46	16.0	9.3	9	9.7	8.8	755.6	2,776.9	2,021.3	2,665.7
15 September 2013	16:00 WIB	30	15.0	9.2	9	9.7	8.6	755.6	2,776.9	2,021.3	2,645.3
30 September 2013	6:00 WIB	15	14.0	9.2	9	9.7	8.44	755.6	2,776.9	2,021.3	2,662.5
23 September 2013	6:00 WIB	60	13.0	9.2	9	9.7	8.4	755.6	2,776.9	2,021.3	2,677.0
			32.0	**SHUT IN PRESSURE**							

From the test results, an output curve is drawn versus the WHP as well as estimates of the output generated at a target separator pressure of 9 kscg or 9.7 bara. Figure 3 shows the output curve for different WHP, indicating the maximum -shut in pressure of 32 which is close to reservoir pressure at 1800 meters.

Figure 4 shows the match between the generated and the simulated output curves with WHP replicating the field measurements.

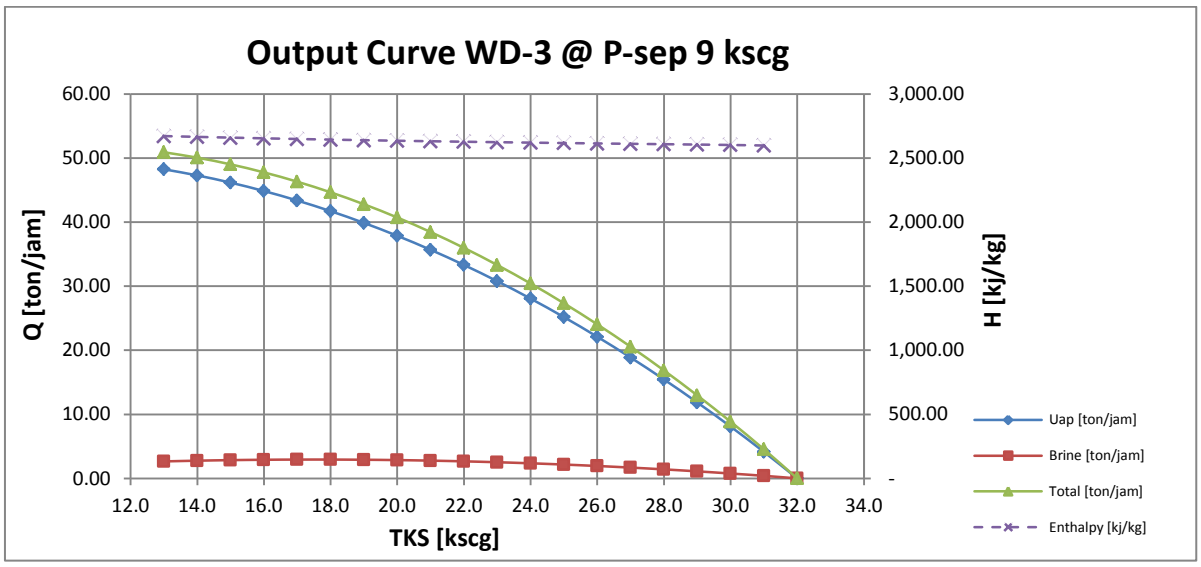


Figure 3. Output Curve

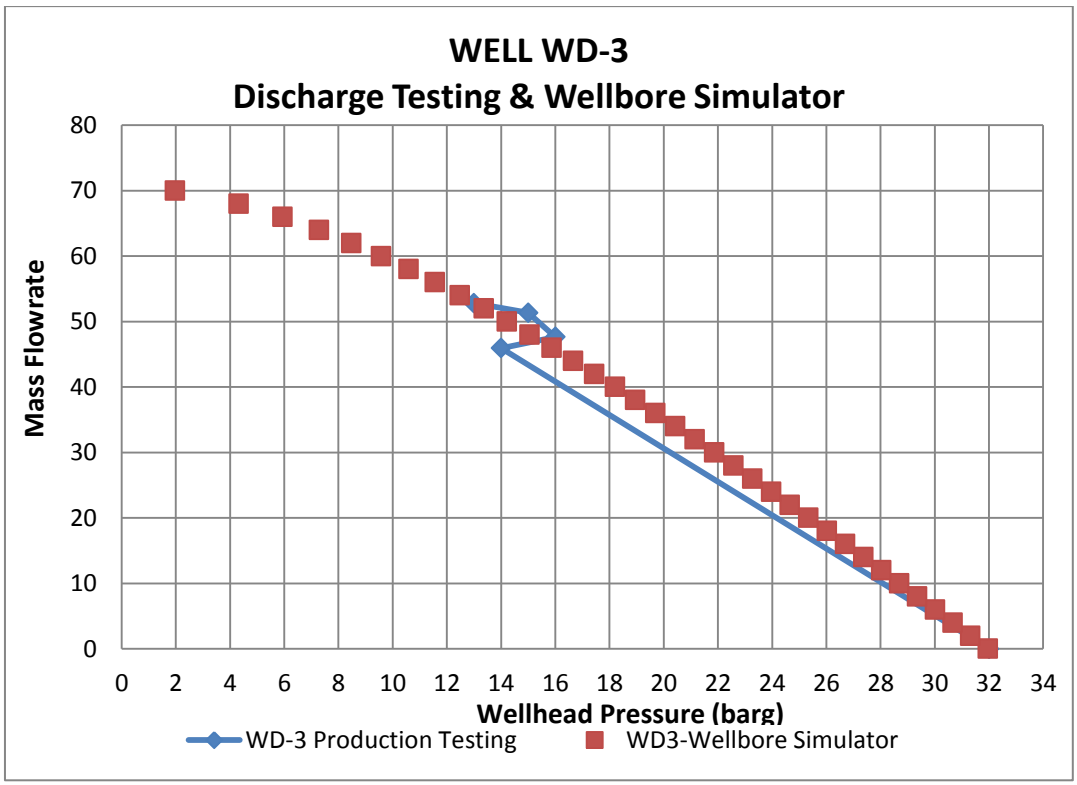


Figure 4. History Matching

4. CONCLUSION

The preliminary unfavorable test results from Well WD-3 in this field suggests the importance of recognizing wellbore damage from the beginning. Correlation with the performance of nearby wells is also important.

The application of the Huff and Puff method demonstrated that wellbore cleaning could be achieved on damaged wells that could result in converting poor performing wells to commercial wells. The use of a compressor and two-phase injection from a nearby well will enable the execution of this method without incurring huge costs. With huff and puff method, a stable discharge can be achieved with the well clean of drilling fluids and other debris.

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