Proceedings World Geothermal Congress 2000
Kyushu - Tohoku, Japan, May 28 - June 10, 2000

EVALUATION OF STEAM PRODUCTION DECLINE TRENDS IN THE KAMOJANG GEOTHERMAL FIELD

Doddy S. Sasradipoera[1], IK Sujata[1], Uum Komaruddin[2]
[1]PERTAMINA Kamojang Geothermal Field, PO Box 120 Garut 44101 Indonesia
[2]PERTAMINA Geothermal Division, Jakarta Indonesia

Key Words: geothermal, decline, production, Kamojang field, Indonesia

ABSTRACT

The Kamojang geothermal field is currently producing about 1100 tons/hour of steam supplying three turbines with 140 Mwe of installed capacity. The turbines are supplied by steam from 31 wells which is delivered through 4 main pipelines.

The decline of steam flow rate of production wells in the Kamojang fields has been analyzed using type-curve exponential and harmonic matching decline models. The decline rate observed shows a larger decline rate in some low producing wells within the low permeability regions. Most of the low producing wells are operated at low WHP, which caused an exponential decline trend due to silica deposition.

There are 3 injection wells operating in the center part of the field. Some production wells which are near to the injection wells tend to have a smaller decline rate. Superheating occurs in some of the wells in the South and West side of the field, based on down hole temperature measurement. The affect of injection wells in operation are also analyzed and discussed.

1. INTRODUCTION

Kamojang geothermal field is located 32 km south of Bandung, capital of West Java province. A field size of 14 km^2 has been determined by DC-Schlumberger (Hocshtein, 1975) and a further field delineation to 21 km^2 determined from the CSAMT (Sudarman et al, 1988). 67 Wells have been drilled in this area since 1974, 53 wells are located in the main production area, and 10 wells are drilled for future extension of another 60 MWe (Figure 1).

The field is a vapor dominated system and has been commercially operated since 1983. At present Kamojang field is producing about 1100 tons/hour of steam through 30 production wells supplying three turbines with a total of 140 MWe of installed capacity.

2. BACKGROUND

2.1 Production Facilities

The steam is supplied to the power plants through four steam transmission lines : PL-401, 402, 403 and 404 (Fig 2). The steam flow is directed to a header before distribution to each power plant. A venting system to take care of pressure fluctuation is operational.

Each pipe group in the transmission system is constructed without connection to each other, so that decreasing flow in one of the main steam transmission line could not be compensated by others. The system, in the face of production declines has limited the ability to keep the flow rate constant.

2.2 Production History

Commercial production in the Kamojang field started in early 1983 with an installed capacity of 30 MWe. About 240 tons/hr of steam is produced for the Unit I turbine through 6 production wells (KMJ-11, 12, 14, 17, 18 and 20).

In September 1987, 2 additional turbines of 55 MWe each (Unit II and III) were put in operation to utilize steam from 20 additional wells (KMJ-22, 24, 25, 26, 27, 28, 30, 31, 34, 35, 36, 37, 38, 39, 41, 42, 43, 44, 45 and 46) , bringing the total electric generating capacity of the Kamojang field to 140 MWe. About ±1100 tones/hour of steam is produced to feed the power plant (Fig 3). Overall, the Kamojang steam field system has had approximately 20% decline in steam deliverability from 1987 to the end of 1991 (GENZL, 1992). The mass output of steam has been maintained by lowering operational wellhead pressure.

Since then, 7 make-up wells (KMJ-51, 52, 62, 63, 65, 67 and 72) have been drilled in the area to maintain the steam supply for the 140 MWe power plant.

Until March 1999, about 121.3 millions tonnes of steam had been extracted from the field.

2.3 Re-injection Wells

Three deep unproductive wells, situated in the center of the field have been used as injection wells. At first, injection wells KMJ-15,21 and 32 were used for waste of condensation from the power plant. The existing 140MW Power Plant produces 80-100 l/s which is composed entirely of cooling water blow down. To increase the re-injection rate, water from the Cikaro dam at the center of the field is pumped to the injection well.

Data from the injection history from well KMJ-15 reveals that re-injection started as early as March 1983 and then through to July 1983 with injection rate of 15 l/s. It was then restarted in December 1983 until October 1984 with an average rates of 11 l/s and then continued again in January 1988. Since August 1994 up to the present, well KMJ-15 has not been used for injection, due to reduction in clear depth above the feed zones of the well.

Injection from well KMJ-21 was started since January 1988 until 1997 with an average rate of 21 l/s. It was reactivated again in September 1998 up to present with an average rate of 28 l/s. Meanwhile since February 1988 until September at the same year, re-injection from well KMJ-32 was activated with an average of 22 l/s. Starting from February 1989 until today present with an average rate of 23 l/s, well KMJ-32 was activated.

3. DECLINE CALCULATION

3.1 Data collecting

To assess the decline, available well testing data are used carefully and analyzed relative to the original well output characteristic of each production well to determine the change. Unfortunately, no periodical well testing to obtain the output characteristic of the wells is available, due to the limited availibility of standby wells available shutdowns of the power plant.

Down-hole pressure measurement from production wells were conducted during shutdowns of the power plant when the well is on bleed, usually once a year. The pressure in the well at the feed-zone can be assumed to be approximately equal to the pressure within the reservoir as long as the bleed rate of the well is small (GENZL, 92).

3.2 Methodology (Type Curve Matching)

Flow rate data from the production wells were normalized using the back pressure equation as follows :

$$Wn = \frac{(Pts^2 - Ptf^2)^n \cdot W}{(Pts^2 - Pst^2)^n}$$

where :

Wn	=	normalized flow rate, ton/hr
W	=	flow rate at *Ptf*, ton/hr
Pts	=	Surface pressure, ksc
Ptf	=	Surface flowing pressure, ksc
Pstd	=	Standard flowing wellhead pressure, ksc
n	=	Exponent of back-pressure equation

The type curve empirical rate-time decline as a base of matching is as follows, using the general production equation of Arps,1945 :

$$q(t)/qi = (1 + b.D.t)^{-1/b}$$

where b=0 for exponential derivative and b=1 for harmonic derivative. Based on the equation above, a dimensionless production rate versus time curve can be plotted into the log-log graphic with a dimensionless equation for :
production rate $(qDd)=q(t)/qi$ and dimensionless time $(tDd)=D.t$

The monthly averaged operational flow rates of all Kamojang production wells were normalized to current operational wellhead pressure (March, 1999) plotted against time (month) on log-log paper to the same scale as the composite analytical-empirical solution type curve.

Table 1 summarizes the results of the decline calculation. A linear trend line curve was also calculated as a comparison.

4. RESULT AND DISCUSSION

4.1 Results

The decline rate obtained using the type curve matching for Kamojang field is 7,43% per year, compared with the conventional method used with a linier regression which is slightly lowerer (6.30%, see tabel-1).

Figure 5 through 8 shows the result of the plots. Production well KMJ-36, 44, 51, 62 and 72 are located a fault target in the northern part of the field. KMJ-36, KMJ-51 and KMJ-62 are the biggest production well along with well KMJ-18. A greater decline rate occurs in KMJ-36 and KMJ-44 (Figure-5), this is most likely due to drilling of make-up wells nearby.

In figure 6, well KMJ-25 and KMJ-39 represents a well which has low productivity index as shown in table 1. KMJ-39 has a decline rate of about 26%/ year. Reparation of the well have been done to clear the scalling occurred in the bore-hole. These two wells are operated at a low well head pressure which accelerates the decline in output.

Figure 7 shows the decline of flow rate of KMJ-11 which represents a moderate Productivity Index and KMJ-52 in figure 8 represent a high Productivity Index which has a low decline rate.

The pressure and temperature profile of the wells mentioned above is shown in figure 9 and 10. They show a correlation with the initial productivity index obtain from the initial output curve. They show a significant decrease compared to the initial data. Figure 11 shows the a reduction in clear depth above the main feed zones which was predicted to be related to the severe decline of flow rate in KMJ-39 and KMJ-25.

4.2 Profile of Production Decline Around Re-injection Wells

As mentioned before, the main pipe distribution of production in Kamojang field is divided into four groups, which is PL-401, 402, 403 and PL-404. From the whole existing main pipelines, only the production wells in PL-401 and PL 403 are located near the three injection wells. Injection well KMJ-15 located near the production wells for PL-401, KMJ-32 near the production well for PL-403 and injection well KMJ-21 which is located near the production well between PL-401 and PL-403 as shown in figure 1. The other production wells for PL-402 and PL-404 are located further away.

Based on the decline calculation with type curve matching and conventional (linear regression) as presented in table 1, PL-401 and PL-403 which are located near the three injection wells have a relatively low decline rate as compared to PL-402 or PL-404. This is presumably because of fluid being supplied near the injection wells. It could also be influenced by natural recharge coming most probably from west, southwest and north of the field (Figure 4).

According to a P/Z method analysis (Bringham and Morrow, 1977; Atkinson et al, 1978,1978c; Economides and Miller, 1985; Dee and Bringham, 1988; Ramey,1990), in the equation:

$$Wsp = Wsi - \frac{Wsi \times Zi}{Pi} \times (P/Z)$$

The cumulative production of steam is directly related to pressure. If the present static pressure is thoroughly studied using the analytical method mentioned above up to the end of

March 1999, a conclusion could be drawn that a reduced static pressure of productive wells located near the injection well is observe relative low than production wells that are located further from injection wells.

Table 2 shows that the static pressure decline of reservoir located near injection wells are lower. This proves that through injection equilibrium of fluid mass will be better maintained.

The same result was also presented by BATAN (National Atomic Energy Agency) through its tracer test study in Kamojang. It shows that more than 70% of re-injected water of well KMJ-15 flows into well KMJ-11,14 and 18. On top of that according to calculation (also by BATAN) with a time breakthrough of 7 years, a contribution of injection water from well KMJ-15 to field steam production is about 5%.

5. CONCLUSION

1. Type curve matching was used to estimate the flow rate decline of 7.43% for Kamojang Field.
2. Re-injection in Kamojang field plays an important role in sustaining the mass balance in the reservoir
3. That a reduced static pressure of productive wells located near the injection wells is lower than those production wells that are located further from injection well.

ACKNOWLEDGEMENTS

We thank the management of PERTAMINA for permission to publish this paper.

REFERENCES

Bringham and Morrow, (1977). P/Z Behavior for Geothermal Steam Reservoir, SPEJ December.

Enedy, K.L., (1991). The Role of Decline Curve Analusis at the Geysers. Geothermal Resources Council, Monograph on The Geysers Geothermal Field, Special Report No. 17.

Fetcovich, M.J. (1980) Decline Curve Analysis Using Type Curve. Journal of Petroeum Technology, June , pp.1065-1077.

Sudarman,S., Boedihardi, M., Kris Pudyastuti, and Bardan. (1995). Kamojang Geothermal Field : 10 Years Operation Experience. World Geothermal Conference 1995, Florence, Italy.

Whitting and Ramey. (1969). Application of Material Energy Balances to Geothermal Steam Production. Journal of Petroleum Technology, July.

Abidin Z., Fauzi A., Sidauruk P. (1998). Isotop Monitoring in Kamojang Field, West Java, PERTAMINA Internal Report.
Barnett, B., GENZL/SMS. (1988). Reservoir Assessment of the Kamojang Geothermal Field. PERTAMINA Internal Report.

GENZL. (1992). Reservoir Review and Simulation of the Kamojang Field Relating to Production Decline and Steam Supply for an Additional 1 x 55 Mwe Unit, PERTAMINA Internal Report.

POKJA KAMOJANG Team. (1995). Feasibility Study of Development of Kamojang Geothermal Field (in Indonesian). Geothermal Division, Directorate Exploration and Production PERTAMINA.

Brown, K.E., (1984). The Technology of Artificial Lift Methods. Volume 4, PennWell Publish Company. Tulsa, Oklahoma.

Hanano, M., (1996). "Vapor Dominated System" : Their Characteristics and Development. Group Training Course in Geothermal Energy. Kyushu University, Japan.

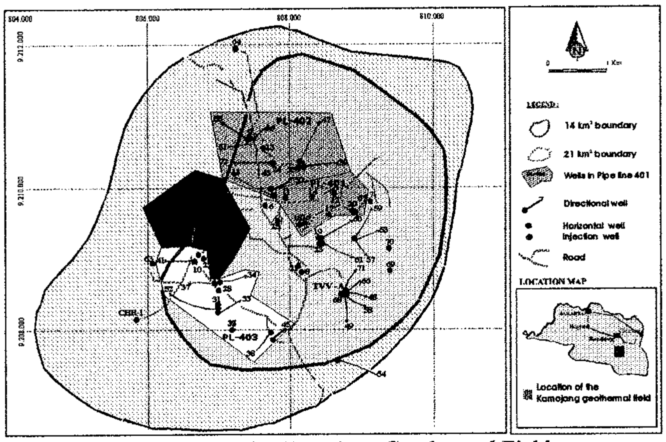

Figure 1 : Area Map of the Kamojang Geothermal Field

Tabel 1 : Estimate of Production Decline (March,99)

WELL	CURRENT PRODUCTION MARCH 1999 WHP (Ksc)	Q (t/hr)	METHOD: TYPE CURVE MATCHING, MATCHING POINT t_D	t (Month)	% year	t/hr year	LINIER % year	t/hr year	TYPE DECLINE	REMARKS	Rate Initial (t/hr) @WHP=15 Ksc	Initial Static Pressure (Ksc)	PI Initial t/jt x 10² / Ksc²	REMARKS
[illegible]														
KMJ-11	13.28	69.44	0.170	100	2.04	1.42	1.93	1.36	H	-	62.65	32.8	9.74	Notes :
KMJ-14	7.91	44.20	0.180	100	2.16	0.95	1.99	0.88	H	-	63.35	33.0	7.33	H (Harmonic)
KMJ-17	12.38	60.81	0.047	100	0.56	0.34	0.69	0.42	H	-	70.76	32.0	8.66	E (Exponential)
KMJ-18	15.68	95.40	0.103	100	1.24	1.18	0.95	0.91	H	-	109.84	32.2	13.53	C (Change of decline)
KMJ-67	16.01	56.36	0.930	100	11.16	6.29	9.62	5.42	H	-	73.18	28.8	12.11	
[illegible]														
[illegible]														
KMJ-24	7.9	40.41	0.570	100	6.84	2.76	4.90	1.98	H	C	40.59	33.5	4.52	
KMJ-25	7.44	10.01	0.990	100	11.88	1.19	19.28	1.93	E	-	13.55	33.0	1.57	
KMJ-39	7.74	5.46	3.000	100	36.00	1.97	24.64	1.35	H	-	17.26	31.6	2.23	
KMJ-43	8.76	18.69	0.600	100	7.20	1.35	8.46	1.58	H	C	21.98	32.8	2.58	
KMJ-44	6.97	18.72	1.000	100	12.00	2.25	10.63	1.99	E	C	44.65	33.3	5.05	
KMJ-51	14.81	85.11	0.720	100	8.64	7.35	4.68	3.98	H	C	110.77	31.5	14.44	
[illegible]														
[illegible]														
KMJ-22	13.42	76.40	0.300	100	3.60	2.75	5.01	3.83	H	C	80.92	33.5	9.02	
KMJ-28	10.20	30.61	0.305	100	3.65	1.12	1.47	0.45	H	-	47.64	33.2	5.43	
KMJ-31	12.64	27.87	0.600	100	7.20	2.01	4.81	1.34	H	-	41.92	32.4	5.08	
KMJ-33	10.29	16.84	1.900	100	22.80	3.79	18.39	3.06	H	-	16.21	31.0	2.47	
KMJ-34	7.80	21.16	0.990	100	11.88	2.51	7.23	1.53	E	C	44.17	32.9	5.15	
KMJ-37	10.41	66.54	0.110	100	1.32	0.88	1.37	0.91	H	-	70.23	32.4	8.82	
KMJ-38	10.08	19.14	0.510	100	6.12	1.17	8.73	1.67	E	-	29.78	35.0	2.98	
KMJ-41	11.73	72.14	0.195	100	2.34	1.69	1.73	1.25	H	-	60.25	32.8	9.43	
KMJ-45	10.41	21.36	0.500	100	6.00	1.28	2.43	0.52	H	C	39.89	34.0	4.28	
KMJ-52	14.74	39.97	0.600	100	7.20	2.88	4.23	1.69	H	C	42.74	31.3	5.66	
[illegible]														
[illegible]														
KMJ-26	11.50	47.64	0.410	100	4.92	2.34	5.12	2.44	H	-	68.31	34.0	9.49	
KMJ-27	12.97	53.96	0.510	100	6.12	3.30	7.26	3.92	H	-	85.00	33.3	9.62	
KMJ-30	9.04	12.09	1.250	100	15.00	1.81	22.08	2.67	E	C	26.11	33.0	3.02	
KMJ-35	12.78	7.79	2.550	100	30.60	2.38	42.75	3.33	E	-	21.08	33.5	2.34	
KMJ-36	13.00	66.74	0.900	100	10.80	9.37	5.40	4.68	H	C	109.71	33.5	12.29	
KMJ-40	8.09	10.76	2.950	100	35.40	3.81	30.39	3.27	H	-	14.40	31.6	1.86	
KMJ-42	7.23	21.00	1.100	100	13.20	2.77	25.33	5.32	E	-	57.14	32.8	6.72	
KMJ-46	10.07	22.19	0.840	100	10.08	2.24	10.73	2.38	H	-	42.56	32.4	5.16	
KMJ-62	15.30	71.89	0.700	100	8.40	6.04	6.23	4.48	H	-	87.29	28.9	14.30	
KMJ-65	14.67	61.87	2.000	100	24.00	14.85	17.60	10.89	H	C	72.55	29.6	11.14	
[illegible]														
[illegible]														

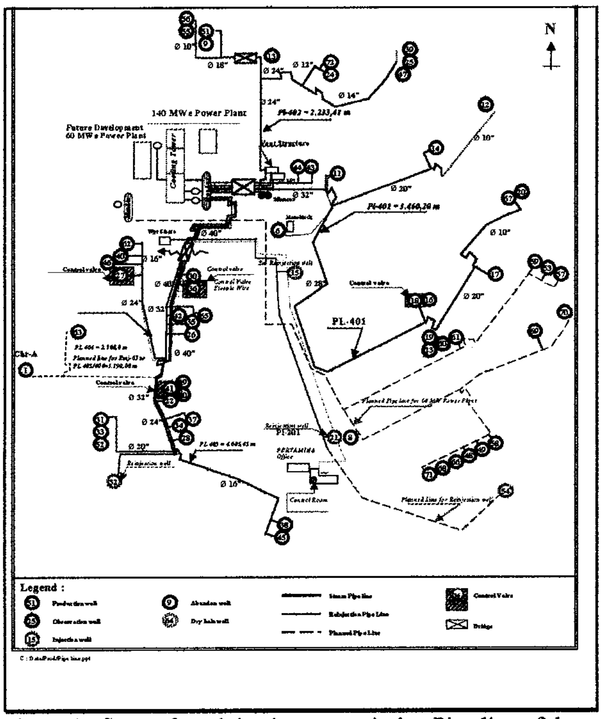

Figure 2 : Steam & re-injection transmission Pipe line of the Kamojang geothermal field

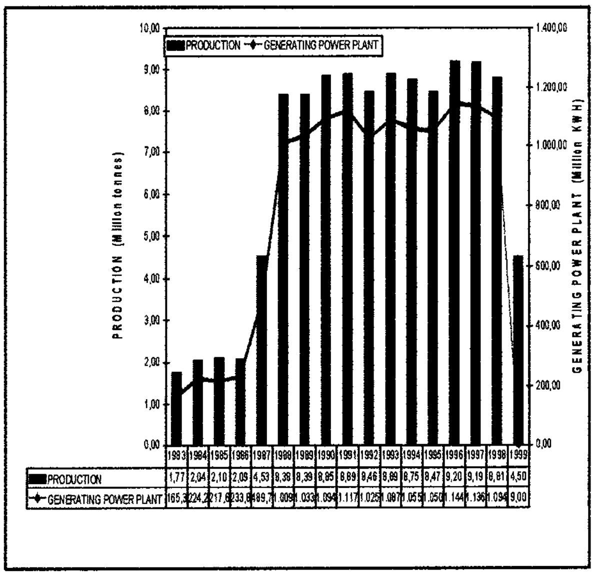

Figure 3 : Production History

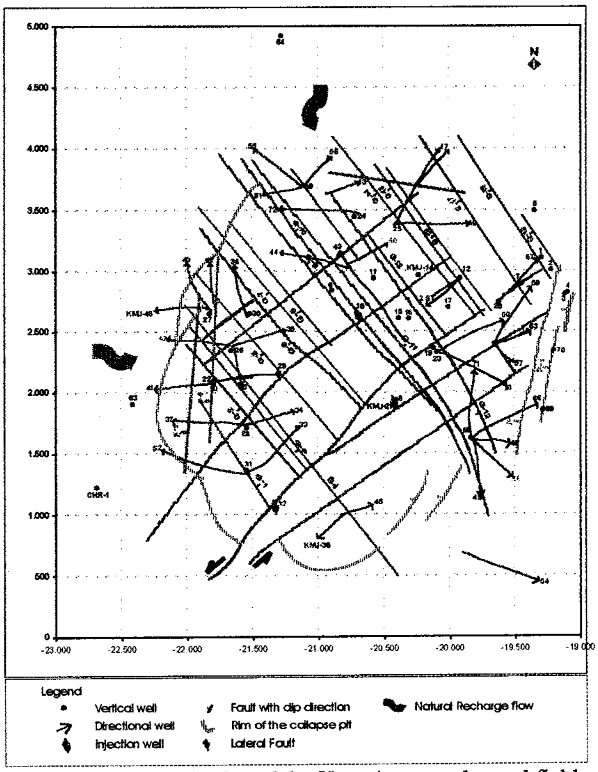

Figure 4 : Structural Map of the Kamojang geothermal field

Tabel 2 : Decline of Reservoir Static Pressure

Well	$Ps_{initial}$ (ksc)	$Ps_{current}$ (ksc)	TimePeriod (year)	Decline Ps per year
Well around injection well KMJ-15				
KMJ-11	32.80	28.41	14.68	0.2990
KMJ-14	33.00	20.18	14.78	0.8674
KMJ-17	32.00	31.48	14.16	0.0367
KMJ-18	32.20	29.87	14.66	0.1589
KMJ-43	32.80	30.71	10.75	0.1944
Average decline Ps per year of production :				0.3113
Well around injection well KMJ-32				
KMJ-28	32.20	26.52	11.00	0.6073
KMJ-31	32.40	24.90	9.58	0.7829
KMJ-33	31.00	27.91	2.83	1.0919
KMJ-34	32.90	22.05	10.49	1.0343
KMJ-38	35.00	27.46	11.16	0.6756
KMJ-45	34.00	24.91	1.41	0.7967
KMJ-52	31.30	30.58	6.16	0.1169
Average decline Ps per year of production :				0.7294
Well which is far from injection well :				
KMJ-67	29.50	26.89	1.66	1.5723
KMJ-25	33.00	28.94	9.14	0.4442
KMJ-39	31.60	20.33	8.97	1.2564
KMJ-44	33.30	19.76	9.32	1.4528
KMJ-51	31.50	29.24	6.14	0.3681
KMJ-26	34.00	21.41	11.48	1.0967
KMJ-27	33.30	25.66	11.58	0.6598
KMJ-30	33.00	20.82	10.13	1.2024
KMJ-35	33.50	23.46	6.77	1.4830
KMJ-36	33.50	27.36	11.57	0.5307
KMJ-40	31.60	27.33	2.68	1.5933
KMJ-42	33.00	17.47	8.72	1.7810
KMJ-46	32.00	20.06	10.41	1.1470
KMJ-62	29.00	26.17	2.33	1.2146
KMJ-65	29.50	27.19	2.22	1.0401
Average decline Ps per year of production :				1.1228

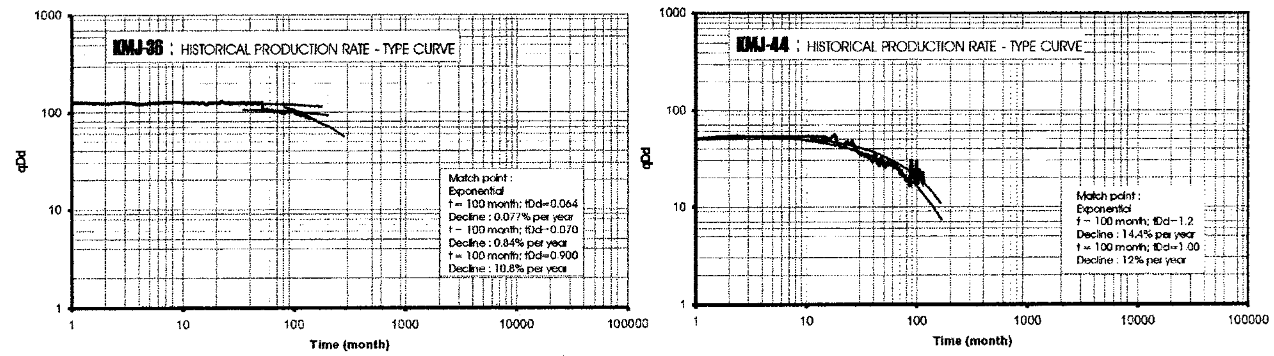

Figure 5 : Type Curve Matching of well KMJ-36 and KMJ-44

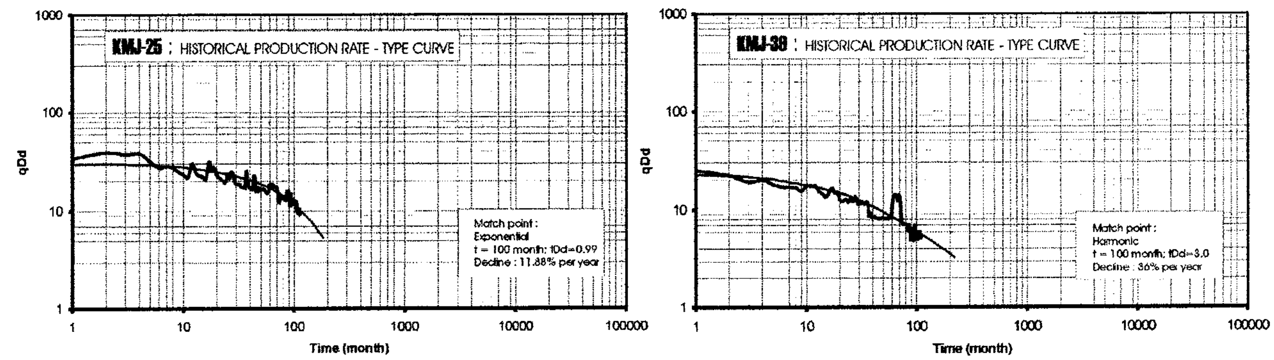

Figure 6 : Type Curve Matching of well KMJ-25 and KMJ-39

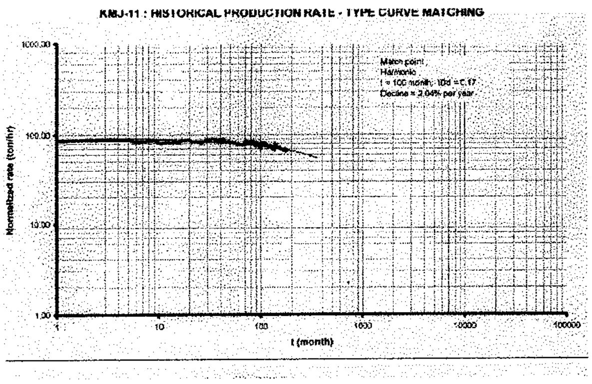

Figure 7 : Type Curve Matching of well KMJ-11

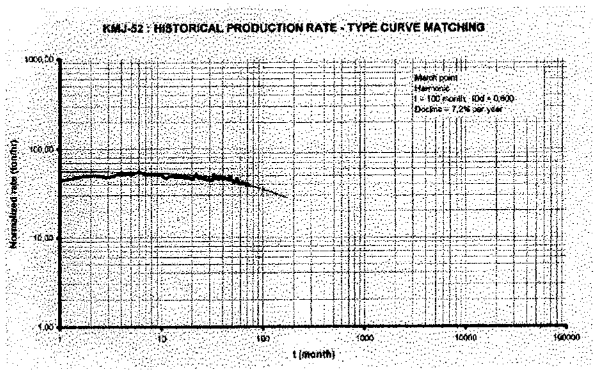

Figure 8 : Type Curve Matching of well KMJ-52

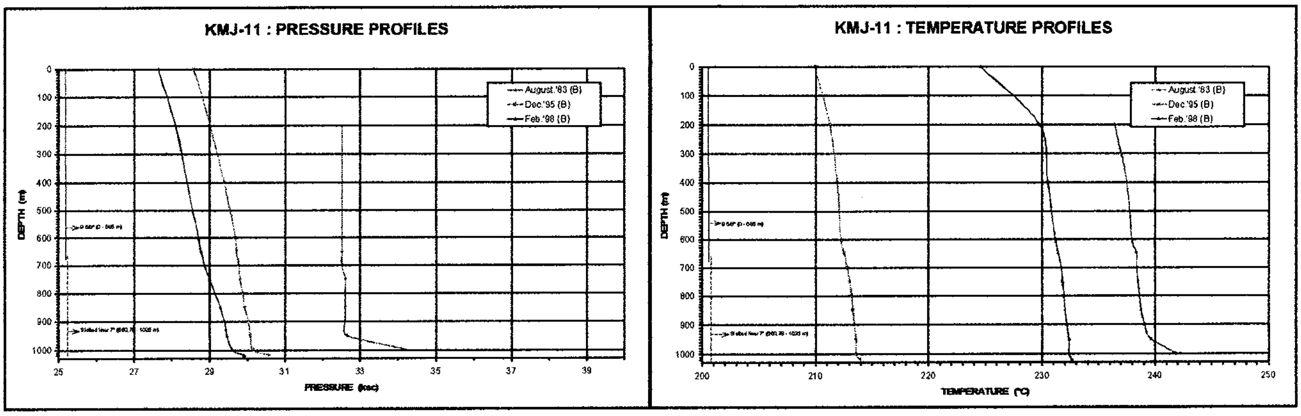

Figure 9 : Pressure & Temperature profile of KMJ-11

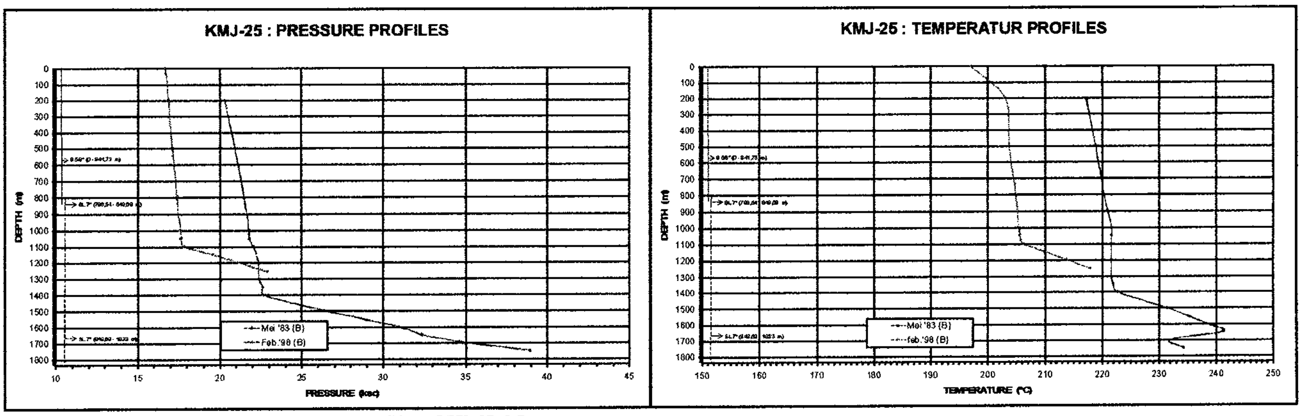

Figure 10 : Pressure & Temperature profile of KMJ-25

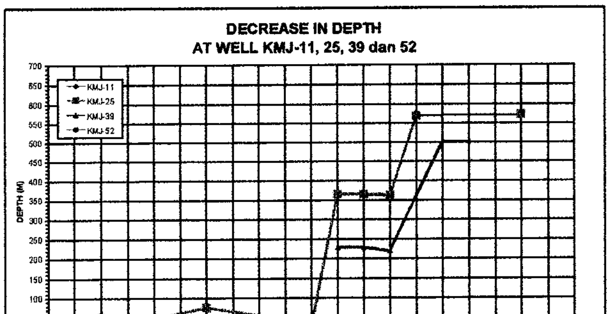

Figure 11 : Reduction in clear depth owf well KMJ-11,25,39,52 obtain from sinker bar.