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# APPLICATION OF TYPE CURVE PROCEDURES FOR THE ANALYSIS OF PRODUCTION DATA FROM GEOTHERMAL WELLS

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## ABSTRACT

It has been already shown[1] that the decline-curve analysis approach can be successfully applied to geothermal wells. It was shown in Reference 1 that by plotting monthly production vs. time on either semilog or log-log paper together with the rate decline models given by Arps[3], it was possible to predict the future production of wells of the Cerro Prieto Geothermal Field.

This paper shows that production forecasting can also be performed by an entirely graphical procedure. The procedure is based on the use of a basic dimensionless graph which was developed by Fetrovich[2]. He found that rate decline models developed by Arps[3] could be placed on a single log-log type curve. The aim of this paper is to show how this graph was used to handle production data from some wells of the Cerro Prieto Geothermal Field. The results obtained from the graphical procedure agreed with those obtained from that procedure reported before[1].

## INTRODUCTION

In spite of the fact that decline curves are one of the most extensively used forms of production data analysis employed in the evaluation of oil reservoirs, there are quite a few published papers on their application to geothermal reservoirs. The results obtained from the application of this type of data analysis to geothermal wells of Cerro Prieto show that the method deserves more serious consideration for application to other geothermal fields around the world.

As it is well known[1,2,3] the three types of declines are exponential, hyperbolic and harmonic. The easiest one to analyze by means of conventional methods[1,3] is the exponential decline, because the hyperbolic decline is difficult to analize either mathematically or graphically. This problem has been overcome with the application of the type curve procedure[2] used in this report. As it can be seen from Figs. 1 thru 4, the basic dimensionless graph provides the type of decline, and if this decline turns out to be hyperbolic, the exponent of the equation describing this type of decline can also be determined.

## FUNDAMENTAL CONSIDERATIONS

Fetrovich[2] showed that the exponential decline is actually a longtime solution of the constant-pressure case[6]. He presented a dimensionless graph in wich the exponential, hyperbolic and harmonic decline models were brought together. This graph is the basis for the analysis presented in this paper. The basic equations for the analysis are[1,2,3] as for follows:

$$W(t) = W_i \quad (1 + bD_i t)^{\frac{1}{b}} \quad \ldots (1)$$

Eq. (1) corresponds to a hyperbolic decline. If b=0, the exponential decline is obtained

$$W(t) = W_i \exp(-D_i t) \quad \ldots (2)$$

Finally, if b=1 from eq. (1) the harmonic decline is obtained

$$W(t) = W_i \quad (1+D_i t)^{-1} \quad \ldots (3)$$

The decline models given by eqs. (1) thru (3) were plotted as a set of log-log type curves in terms of dimensionless mass flow rate, $W_D$, and dimensionless time, $t_D$. The dimensionless variables are defined as follows[2]:

$$W_D = \frac{W(t)}{W_i} \quad \ldots (4)$$

$$t_D = D_i t \quad \ldots (5)$$

## APPLICATION OF TYPE-CURVE MATCHING TO CERRO PRIETO WELLS.

The type-curve matching is not new; it has been applied for several years in analyzing constant rate pressure tran sient data in both oil and gas wells[7, 8, 9] the procedure is as follows:

The field data are graphed on a tracing paper sheet having exactly the same size log-log coordinates as the type-curve. Next the field data curve is positioned over the type-curve, moving it so that the axes are kept parallel until field data match uniquely any one of the decline curves.

The final step of this procedure is illustrated in Figs. 1 thru 4 showing different types of match. The dashed lines in these graphs correspond to real coordinate axes; meanwhile, those variables within the dashed squares are real variables. Field data are shown as circles. Dimensionless coordinated axes are shown as continuous lines as well as the basic decline curves.

The type-curve analysis was applied to 18 producing wells of Cerro Prieto. They exhibited the three types of decline. Figs. 1 and 2 correspond to wells A and B that showed a harmonic type of declination. Fig. 3 illustrates the behavior of a well with a hyperbolic decline. From this figure it is evident that the last two points fall apart from the general trend, it is because of severe scale problem within the producing casing string which reduced drastically the productivity of the well. Well A exhibited an exponential decline as is evident from Fig. 4. Sometimes it is not possible to obtain a unique match of all of the field data points with a single curve as is illustrated in Fig. 5. The behavior of this well is believed to be due to a slowly increasing scale build-up at either the casing producing string or at the slotted linner.

The main advantage of the procedure described in this paper is that production forecasting is made by extending the line drawn through the field data points according to the dimensionless curve from the basic type-curve that uniquely matched the data points. Future production rates corresponding to any time are read directly from the real axes. The application of decline curve procedures, both the one described in this paper and that used in Reference 1, to Cerro Prieto wells on a monthly basis during 1977, produced results that agreed within 6.8 per cent for both steam and total mixture production, between the rates predicted from the theory to the production rates actually measured in the field.

## NOMENCLATURE

$b$ = decline curve exponent

$D_i$ = initial decline rate, $t^{-1}$

$t$ = real time, (months for $t_D$)

$t_D$ = dimensionless time, (eq. 5)

$W_i$ = initial mass flow rate, ton.

$W(t)$ = mass flows rate at time t; ton.

$W_D$ = dimensionless mass flow rate, ton.

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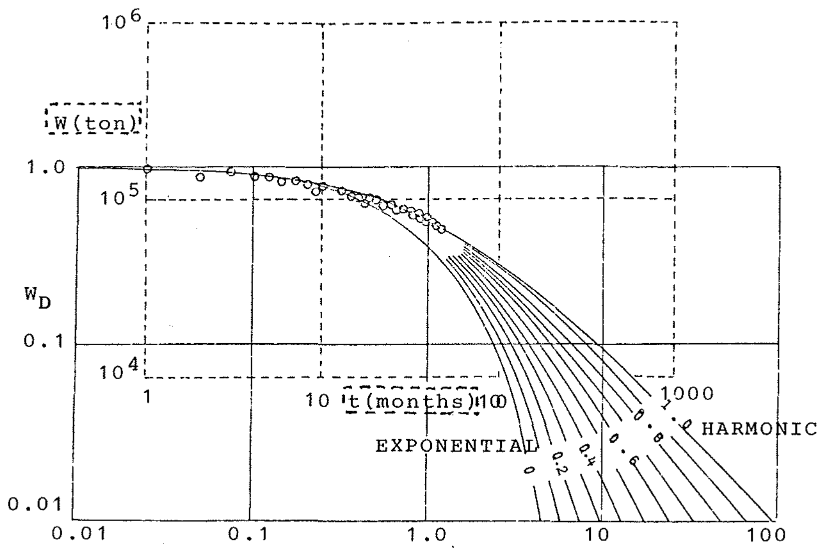


Fig. 1 Type-curve matching for well A

------ Graph on real variables, W vs. t

——— Basic graph on dimensionless variables, $W_D$ vs. $t_D$

0 Field data points

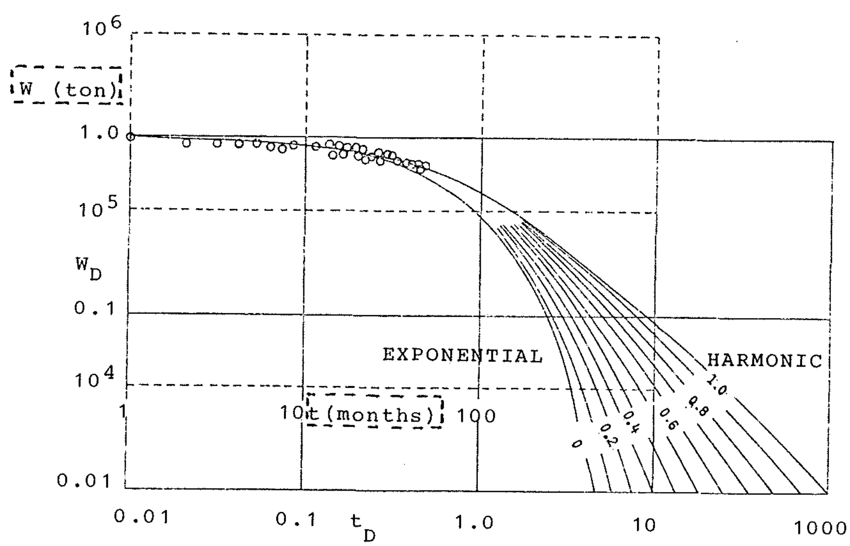


Fig.2 Type-curve matching for well B

---- Graph on real variables, W vs. t

—— Basic graph on dimensionless variables, $W_D$ vs. $t_D$

o Field data points

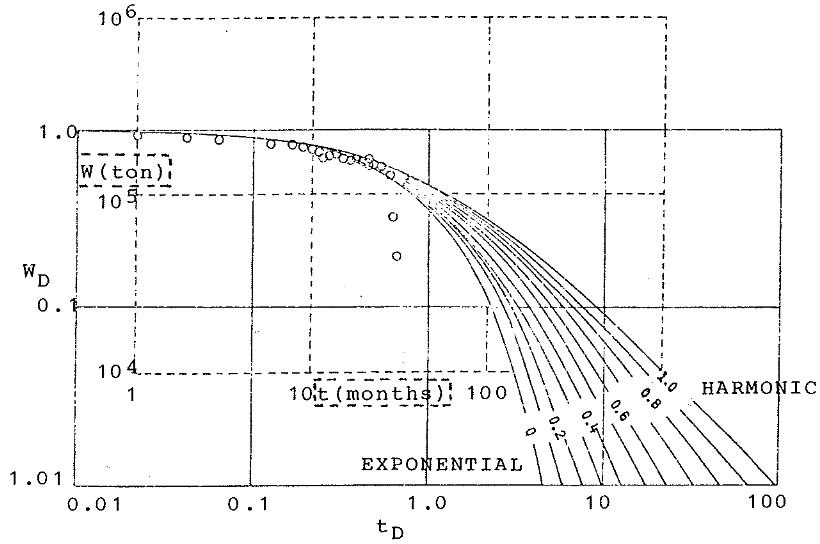


Fig. 3 Type-curve matching for well C
----- Graph on real variables, W vs. t
——— Basic graph on dimensionless variables, $W_D$ vs. $t_D$
o Field data points

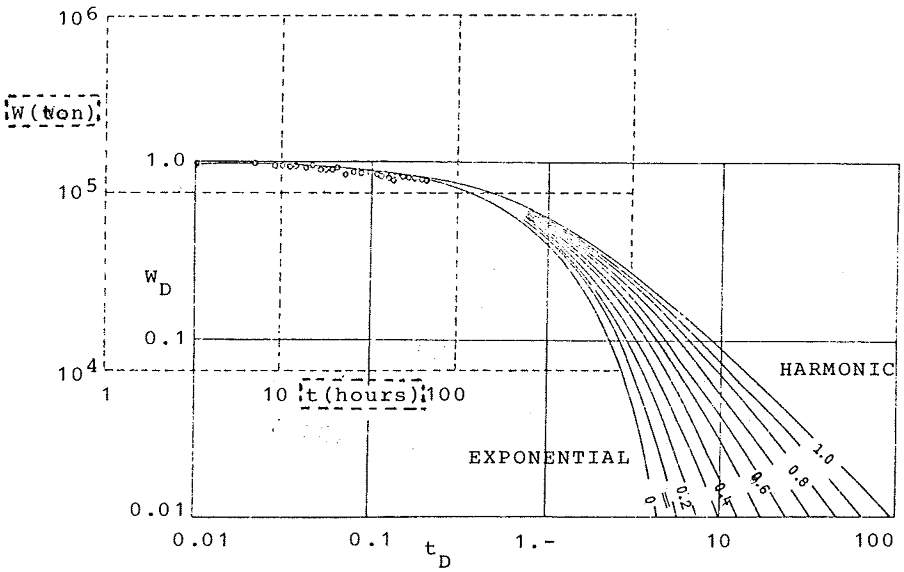


Fig. 4 Type- curve matching for well D
----- Graph on real variables, W vs. t
——— Basic graph on dimensionless variables, $W_D$ vs. $t_D$
o Field data points.

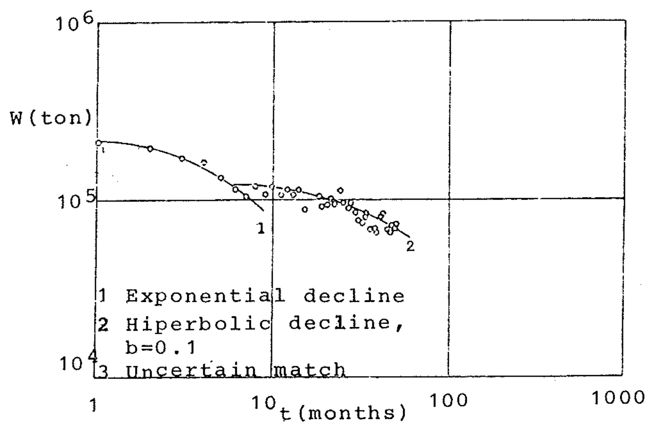


Fig. 5 Type-curve matching for well E.
o Field data points