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# CERRO PRIETO STEAM PRODUCTION FORECASTING

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## Abstract

Steam production forecasting is always the main concern for the management of any geothermal field, but it is also an important goal for the reservoir engineering team. For a long time, engineers and scientists have used numerical simulators, trying to match a field's actual behavior with predictions from modeling.

This paper summarizes CFE's experiences using a "hand made simulator" based on 20 years of steam production and power generation at Cerro Prieto Geothermal Field.

Annual production decline curves, reservoir pressure and temperature histories, drilling and workover statistics, as well as load factor and turbine efficiency data forms a huge dataset that, after several adjustments, we have developed into an useful tool to predict steam and power production with reasonably good accuracy.

## Introduction

Exploitation of Cerro Prieto began in the 1960s, when the Comisión Federal de Electricidad de Mexico (CFE) drilled the first wells in the Mexicali Valley, Baja California, Mexico. Since then, CFE has been developing and operating this geothermal field, drilling more than 200 wells in the area. The average depth of these wells is between 1,500 and 3,000 m, and the deepest well is 4,000 m.

Generating approximately 5,000 GWH during 1993, Cerro Prieto supplied up to 72% of the electrical needs in the northern part of Baja California, Mexico. With a constant withdrawal rate of 3.2 $m^3$/sec of fluid, the field produces about 5,300 metric tons/hr of steam to feed the nine installed power plants.

More than 110 production wells are connected to the steam gathering system (Fig. 1). The gathering system is interconnected, which allows great flexibility in redirecting steam in the field when wells or the power plants are shut down for maintenance.

Availability of steam is always the main concern, and is affected by day-to-day problems such as death of wells, drilling and work-overs, steam pipe failures, etc. Declines in reservoir pressure due to 20 years of production must also be taken into account.

We have more than 34 monitoring wells, both inside and outside of the producing area of the field, allowing us to monitor the actual reservoir pressure decline. We use old wells that are no longer producing. We have cleaned out some of them to be sure they are well connected with the reservoir. Of course, pressure has not changed at the same rate in all portions of the field. Fig. 2 shows the trend of pressure change in Cerro Prieto after 20 years of exploitation.

As must anyone who operates a geothermal field, we predict the annual availability of steam. By knowing how much steam is available in the field, we can estimate how much power we will be able to produce each year. This is used not only to fix the annual budget for drilling and workovers, but also to allow CFE to plan the National Energy Policy.

We have developed a production simulator to predict steam production and modifications to the steam field needed to maintain production. The mass balance calculations are coupled with steam losses in the delivery system and specific steam consumption for each power plant to predict power production.

To predict steam availability, we balance the negative and positive events that affect daily availability of steam in the field. We consider, as negative effects, death of wells and production decline. Positive events are, of course, drilling new wells, repairing wells, and re-sizing and cleaning orifice plates during summer, which is the season when demand for power is the highest.

We estimate the overall steam production decline in a fixed period with the following equations:

where

$D_{ec}$ = steam decline (metric tons/hr)

$P_i$ = initial production

$$D_{ec} = P_i + E_p - E_n - P_f$$

$P_f$ = final production

$E_p$ = positive events

$E_n$ = negative events.

## Events controlling steam production

### a) Negative events

On the average steam production has declined by some 12% each year; part of this is because of both scaling in the formation and in the wellbore and some is due to a general decline in reservoir pressure.

In Cerro Prieto, we have observed that about 16 wells die or are killed intentionally during a year. The main reason a well dies is because of silica scaling in the wellbore or in the reservoir close to the borehole. A few wells die from mechanical problems related to collapse of casing.

It has been a normal practice to kill wells with either low wellhead pressure or small steam production, in order to perform a work-over and increase their production. Last year 17 wells were repaired, killing 8 wells because either low wellhead pressure or a small steam production. Six of them are now producing more steam that before the work-over. Fig. 3 shows the number of wells that have been repaired each year.

Production decrease due to reservoir pressure decline is another element affecting the availability of steam. We have recorded wellhead pressure behavior and steam production for each well in the field during at least 20 years of production. It is hard to define a general trend for all wells in the field; however, we try to group wells that have similar behavior. Well-defined (e.g., exponential or logarithmic) and chaotic trends have been observed in Cerro Prieto as shown in Fig. 4.

### b) Positive events

Each year, we repair an average of 14 wells in Cerro Prieto. The preferred repair method is to side-track by opening a window in the casing and completing the new hole a few meters away from the old bore at the same level as the original one. This practice has been given very good results, in most cases obtaining a higher steam production than existed production before work-over.

Another work-over practice is to clean wells that are producing from the boiling (two phase) zone. We normally deepen these wells into the liquid (single phase) zone with higher pressures.

Another way to obtain additional steam is by cleaning orifice plates or installing orifices with larger openings. Larger orifices are used in some wells during the summer in order to obtain additional steam production from these wells during this period of high power demand.

Also, there is a permanent orifice plate cleaning program that produces some additional steam from each well; cleanup of about 100 wells annually makes an important contribution of steam to the system.

## Steam and Power Forecasting

The steam balance/power production simulator is used to estimate the availability of steam in the field and the power that will be produced. This program takes into account all the factors we have discussed in previous sections. The input parameters are:

a) Dates (day, month, and year) of the beginning and end of the simulation period.

b) Real or estimated annual work-over and drilling programs.

c) Annual maintenance program for each power unit.

d) Monthly average steam consumption for each unit.

e) Data file with decline curve for each producing well.

f) Steam loss factors.

The program calculates the best fit for each wellhead pressure and production decline curve and creates a file with steam production for units CPI, CPII, and CPIII for the time period.

The produced steam is decreased by the losses of steam from the death of wells, by discharges of steam to the atmosphere due to maintenance of surface installations or power plants, by losses of steam in separators because of low levels and by losses in the steam drains. The difference between steam production and steam losses is steam available for the time period.

In order to balance the available steam for each plant, the program calculates available steam and transfers excess steam from CPII or CPIII to plants that need additional steam. CPI can not transfer steam to CPII or CPIII because CPI has lower separation pressure. The general operating criterion is to provide steam first to CPII and CPIII because they have the lowest steam consumption rate.

Finally, power production is estimated utilizing the steam available and the actual specific steam consumption for each day in the period; a file is created with this information.

## Example: 1993 Steam and Power Prognosis

As an example of the output of this forecasting, we present the results for 1993 between real and predicted steam and power generation. Figures 5.1 and 5.2 show the steam gained by new and repaired wells. Fig. 5.3 shows steam gained from cleaning or providing larger orifices.

Negative effects of steam decline and death of wells are shown in Fig 6.1 and Fig. 6.2. Fig. 6.3 illustrates the sum of positive and negative events.

Predicted and real steam production (initial production for the period plus the sum of negative and positive events) and electrical power production are illustrated in Fig. 7.1 and Fig. 7.2, while specific steam consumption during 1993 is shown in Fig. 7.3.

## Results

Although forecasting for both steam and power were not too bad (less than 2% during summer); we observed some differences between predictions and real data for some of the parameters such as death of wells. During 1993, we had periods of up to 3 months with no deaths, but we observed that up to three wells died in 1 month. That means that this prognosis tool is not too accurate for day-to-day analyses, but for the mid and long term, it has shown very good results.

Substantial experience and common sense in the use of this technique have generated improvements in the use of this tool every year during the last 10 years. Through the use of this software we have been able to evaluate several scenarios and plan further exploitation of the field with a good level of confidence. Use of the model allows us to rationalize development of the field and schedule new drilling and workovers based on estimated pressure declines and projected power demands.

FIG. I ***PRODUCTION WELL 1993***

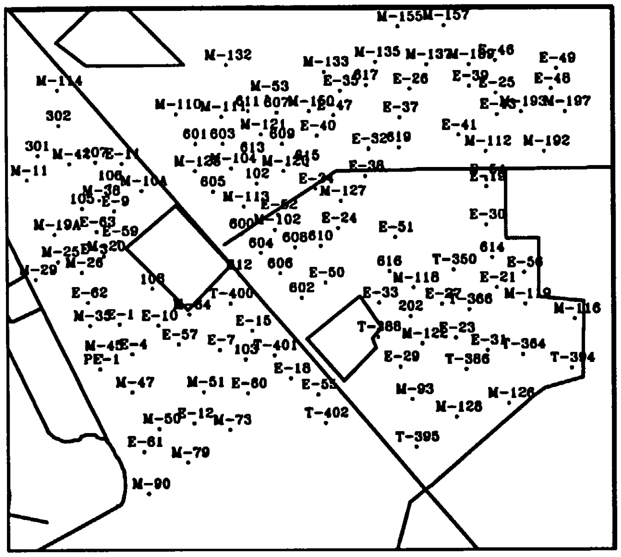

FIG. 3 NUMBER OF WELLS REPAIRED

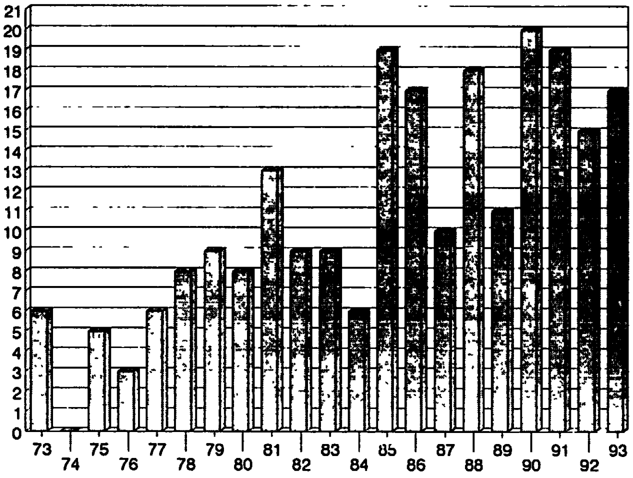

FIG. 2 RESERVOIR PRESSURE CHANGE ( bar/yr )

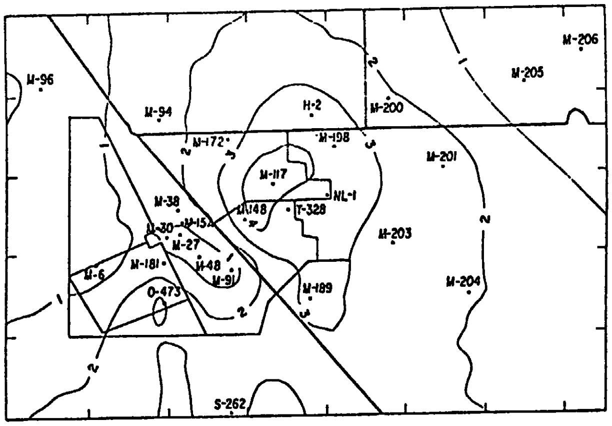

FIG. 4 - BEHAVIOR OF WELLS

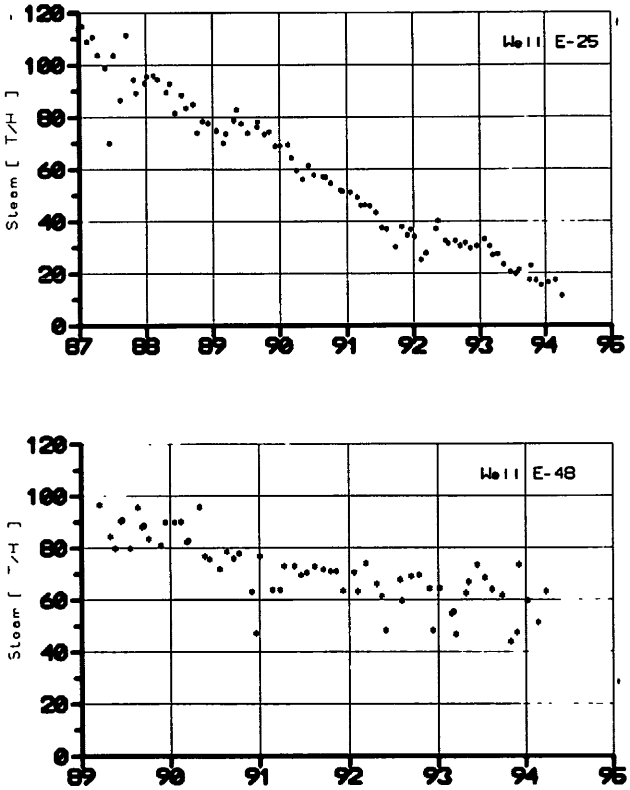

FIG. 5 - POSITIVE EVENTS

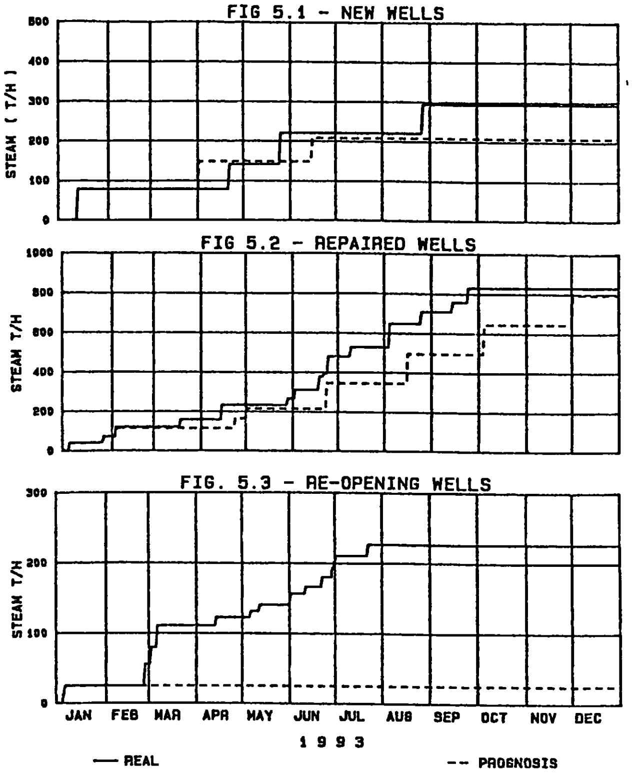

FIG 5.1 - NEW WELLS

FIG 5.2 - REPAIRED WELLS

FIG. 5.3 - RE-OPENING WELLS

FIG. 6 - NEGATIVE EVENTS AND FINAL BALANCE

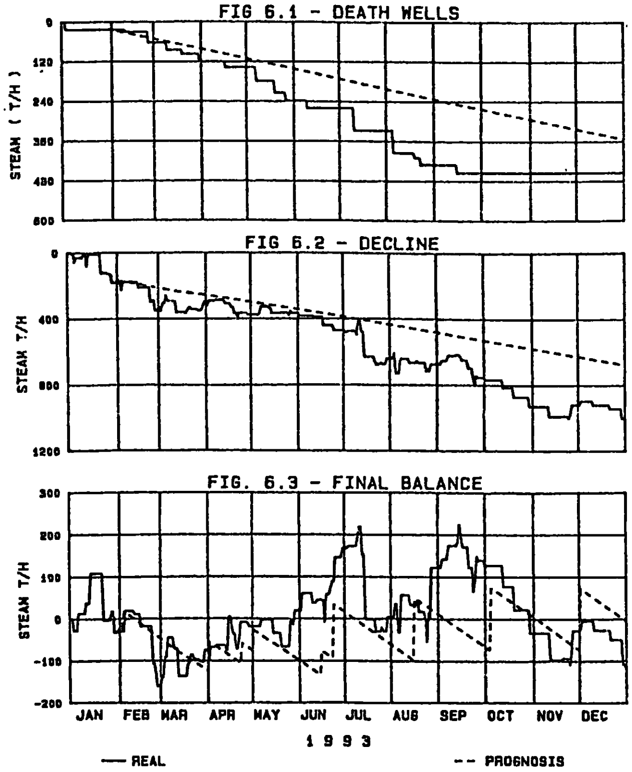

FIG 6.1 - DEATH WELLS

FIG 6.2 - DECLINE

FIG. 6.3 - FINAL BALANCE

FIG. 7 - AVAILABLE STEAM, POWER AND SPECIFIC CONSUMTION

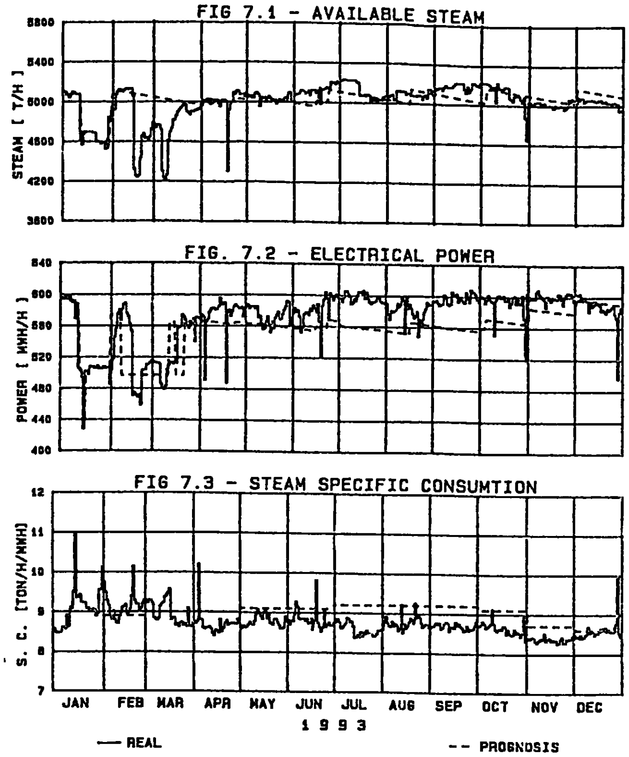

FIG 7.1 - AVAILABLE STEAM

FIG. 7.2 - ELECTRICAL POWER

FIG 7.3 - STEAM SPECIFIC CONSUMTION