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SIMULATION STUDIES FOR WELLS AH-4bis/AH-17 and AH-18, AHUACHAPAN GEOTHERMAL FIELD.

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ABSTRACT.

Well AH-4_{bis} at the Ahuachapan Geothermal Field is planned to be drilled on the same pad as the former AH-4. A simulation study was carried out for two casing diameters 13 5/8 and 9 5/8" in order to estimate its production and to know its economic feasibility. The simulation results indicate a high probability of production in the range of 7 Mwe, equivalent to 120 kg/s total mass flow rate, 1250 kJ/kg at 6 bar-a for the new well AH-4_{bis} .

Well AH-17 is good producer, during 1991 after ten years of production, the well was shut-in due to silica scaling problems. A wellbore simulation was carried out in order to predict the new production conditions after the work-over, mainly to estimate the water flow rate in order to reduce the silica scaling. The results indicate a very low water flow rate. The match between the simulated and measured production curves after the work-over was successful.

The well AH-18 is located at the southern part of the actual bore field. CEL is planning to expand the borefield at this area and it is neccessary to estimate the possible production conditions at that zone. The results indicate a high probabilty of production at that area. The power potential is estimated at 3.5 Mwe per well at WHP 6 bar-a and the wells will not require induction.

INTRODUCTION

The Ahuachapan Geothermal Field is located 3 km away from The city of Ahuachapan at the eastern part of the country. The commercial production of energy began in 1975 when the first 30 Mwe condensing unit came on line. During 1976 a second unit of 30 MWe was installed. Finally during 1981 thrid double-flash unit of 35 Mwe increased the total installed capacity to 95 Mwe.

The steam production for power generation started in June 1975 when Unit 1 went into operation, which required the operation of the producer wells AH-1, AH-4, AH-6 and AH-7. During the exploitation period, the productivity of the field decreased due to a decline in the reservoir pressure and limited drilling of make-up wells.

Wells AH-4, AH-17 are located in the central part of the field, well AH-18 is located at the southern part of the borefield, Figure 1 shows the well sites.

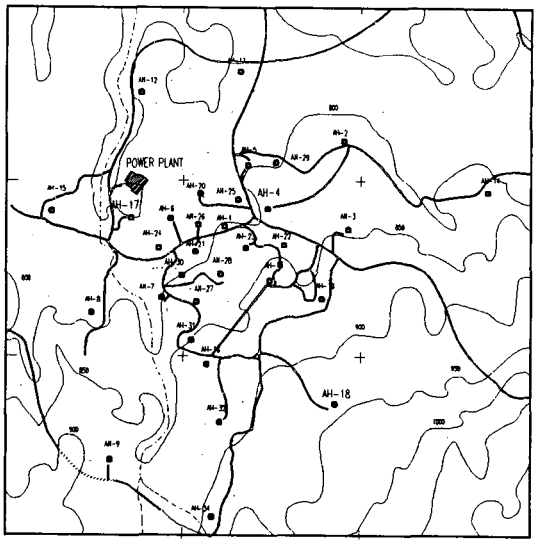

Fig. 1. Well field location

The actual power scheme requires the increasing of the steam production of the field. CEL is planning to carry out some projects or activities in that sense. As part of these activities, the work-over for well AH-17, the drilling of well AH-4bis and the drilling of make-up wells represent an important target for the reservoir engineering studies.

WELL AH-4 bis.

The previous well AH-4 was drilled from June to August 1972, the well site is in the central part of borefield with coordinates 310,835 E and 412,470 N; the casing program was as follows:

Hole diameter	Depth	Casing size	Depth
26"	52 m	20"	50 m
17 ½"	485 m	13 3/8"	481.5 m
12 ¼"	640 m	Open hole	640 m

Well AH-4 was considered a good producer with a total mass flow rate close to 130 kg/s, 23.5 kg/s of steam, 18 % of dryness, 1300 kJ/kg of enthalpy for a Well Head Pressure of 7 bar-a (Witherspoon, 1977). The main feed zone was located between 480 to 600 m depth. In June 1975 well AH-4 went on line in order to contribute the operation of Unit 1. The power capacity of this well was close to 12 Mwe during that period.

Due to possible casing corrosion and poor cementing, CEL in 1982 decided to carry out the work-over operation, the objective was to change the casing design and repair the casing damaged. After it was repaired, the feed zone was cemented. The permeability and the production rates of the well changed and became very low.

In order to increase the steam production of the actual borehole field, CEL is considering drilling a new well on the same pad of the previous AH-4 well, 50 m SE away from the previus well to intersect the original feed zone and fracture for the former well, considering no effect of the cementing no more than 20m away from the center of the previous well (CEL, 1992).

The simulation study was carried-out using the wellbore simulator HOLA. This simulator was developed by Orkustofnun (Iceland); HOLA reproduces the measured flowing temperature and pressure profiles in flowing wells and determines the relative contribution of each feed zone for a given discharge condition (Bjornsson, 1992). The flow within the well assumes steady-state conditions at all times, but time changing reservoir pressures are allowed.

The output curves and some temperature and pressure profiles of well AH-4 were considered as initial or matching conditions due to the lack of flowing profiles.

Figure 2 and 3 shows the total mass flow rate and mixture enthalpy for several output test measured at the former well .

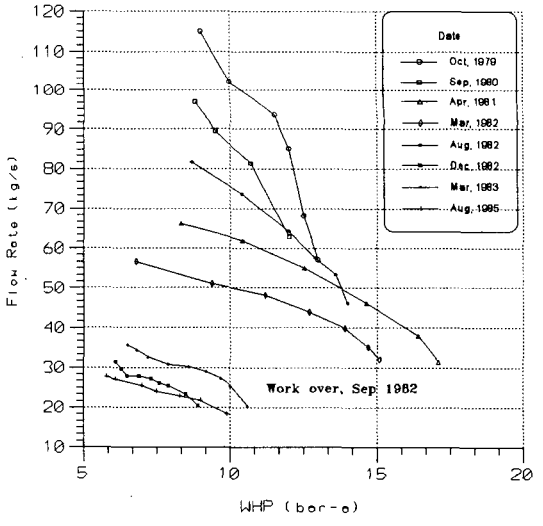

Fig. 2. Output test, well AH-4

The former well, since its start into operation was affected by the pressure drawdown and boiling around the well as observed in Fig. 2 and Fig. 3 but after the work-over the permeability of the well was very low.

The main assumptions and input data used for the simulator were:

a) The production zone is located at 640m depth with a Productivity Index (PI) of $0.9E^{-10}$ kg/s/m^3 similar to well AH-4.

b) The flowing enthalpy for the new well is between 1250 to 1650 kJ/kg.

c) Due to the pressure drawndown, the flowing pressure in the well will be close to 16-18 bar-a and the reservoir pressure is 20 bar-a (actual average pressure of the reservoir).

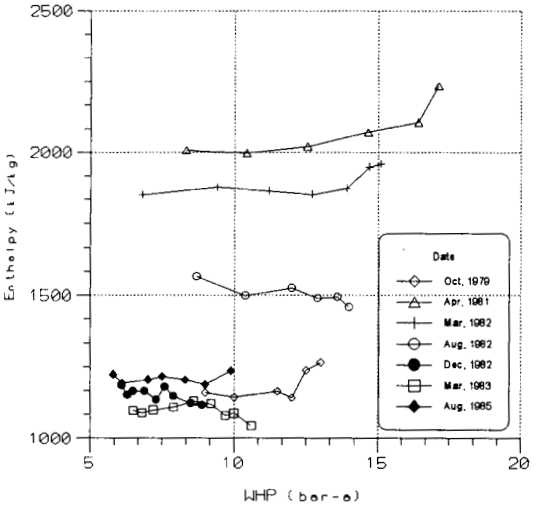

Fig. 3. Discharging enthalpy, well AH-4

Figure 4 shows the matching curve for the simulation adjustment.

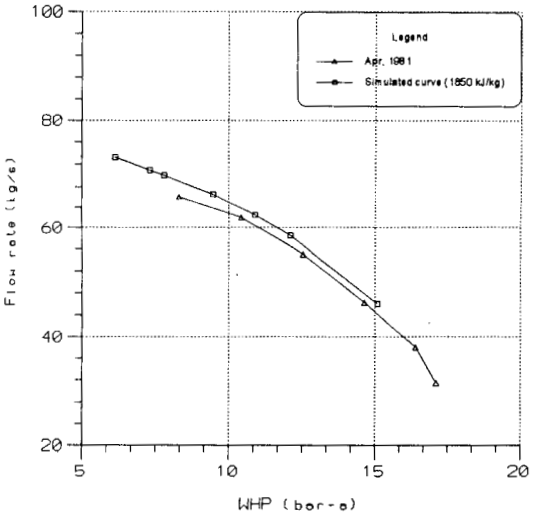

Fig. 4. Simulated and measured output curves

An important role for this simulation is to make a decision about the new well desing, as well as, the new production rate and the estimated output curve for this well. Figure 5 shows the simulated output curves for different liner diameters with constant 1250 kJ/kg enthalpy. Figure 6 shows an integrated curve for 6 bar-a constant well head pressure and enthalpy between 1250 to 1650 kJ/kg.

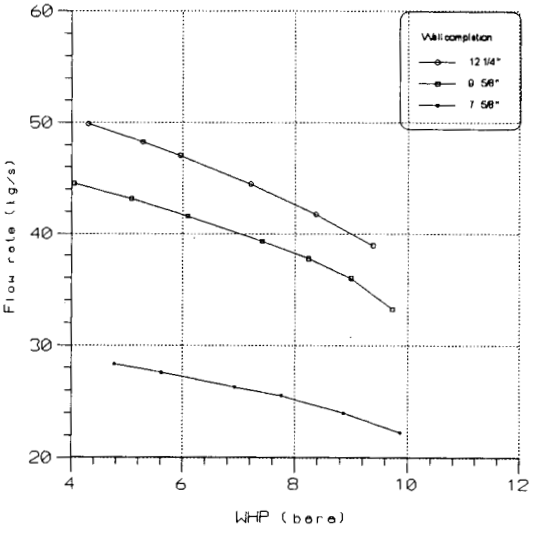

Fig. 5. Simulated curves for different liner diameter

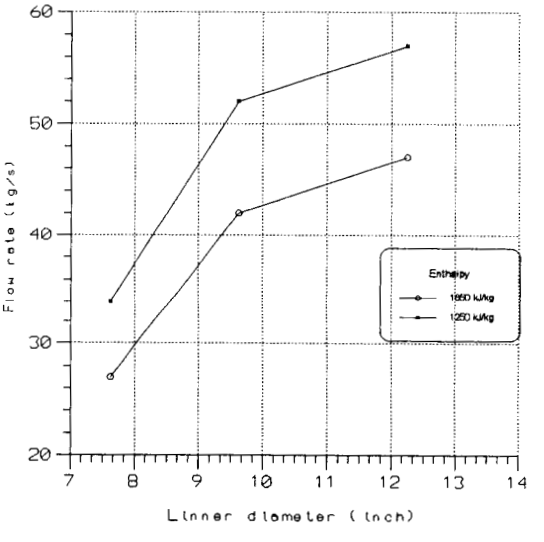

Fig. 6. Flow rate for different liner diameter.

The results of the study suggest the follow:

a) The bottom hole depth of the new well will reach 700 m in order to mantain the same production rates as the former well.

b) The casing design will require 13 5/8" production casing down to 300-400 m depth just on the cap rock of the reservoir and 9 5/8" slotted linner down to the bottom hole.

c) The production of the well AH-4_{bis} will reach 7 MWe for the actual reservoir conditions and similar permeability as the former well; but the liner diameter is reduced to 7 5/8" the production will be 40% lower than 9 5/8".

WELL AH-17.

Well AH-17 is located in the central part of the actual borehole field, its coordinates are 310,781 E; 411,697 N, elevation 773 masl. It was drilled from June to August 1976, the casing desing is the following:

Hole size	Depth (m)	Casing size	Depth (m)
17 ½"	105	13 3/8"	104
12 ¼"	452	9 5/8"	450
8 ½"	1200	7 5/8"	440-1200

The main production zone for this well was located at 480 m depth just on the steam cap of the reservoir. From October 1976 to June 1978 this well was used as an injection well due to the lack of a disposal channel and injection wells. In 1981 a work-over operation was carried out in order to install slotted linner into the open hole.

As this well produces dry steam, in 1981 it was connected to the power station. In 1991 after almost 10 years of continuous production, the well showed silica scaling in the production casing and steam pipeline.

According to CEL's studies and Consultants recommendations (Electroconsult, 1993), the silica scaling could be reduced by increasing the WHP (change on the production characteristics) in order to increase the liquid phase, in this case the silica could be diluted and could move together with the liquid phase.

In 1994 CEL carried out the work-over in well AH-17 in order to clean and remove the silica scaling from the production casing.

A simulation study has been prepared in order to simulate the production and the output test. The main target was to evaluate the liquid phase production and its changes for different WHP. It was also necessary estimate the new production parameter in order to evaluate the silica scaling inside the casing.

Again the wellbore simulator HOLA was used for this work. Two flowing profiles carried out with scaling into the well during 1992 were used for matching purposes. Well AH-17 was modelled with a 7.5" scaling diameter and 100 m scaling length as observed in Figure 7.

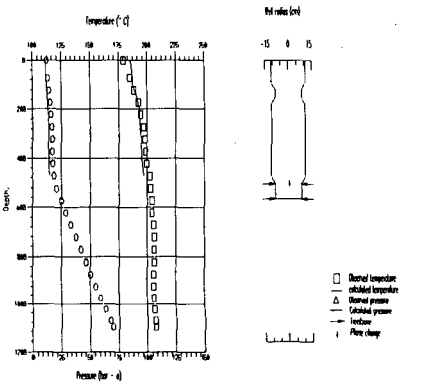

Fig. 7. Simulated and measured curves, well AH-17.

The matching was achieved with a Productivity Index equal to 0.23e-10 kg/s.m^3, the main feed zone was located between 475 to 600 m and a very low permeability at the bottom.

After the work-over operations, the mass flow rate from the well will tend to increase, Figure 8 shows the simulated output test for well AH-17 without scaling. The figure also shows the simulated curve with two measured output curves after the work-over operation, in both cases the error between the measured and simulated curves is less than 20 %.

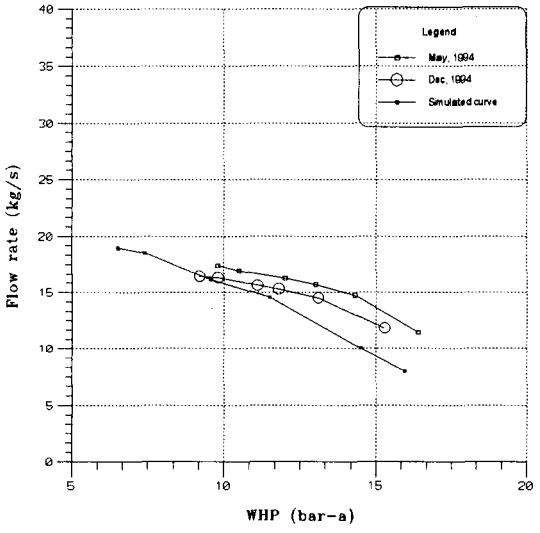

Fig. 8. Simulated and measured output curves, well AH-17.

The simulation results suggest only dry steam production with dryness over 90% (mist flow pattern) for a wide range of WHP, therefore the change in the operation parameters will not increase the liquid phase flow rate for the well AH-17, perhaps due to the steam cap production.

WELL AH-18

Well AH-18 is located at the southern part of the actual borehole field, its coordinates are 309,745 E, 412,852 N and elevation 926 masl. The well was drilled from March to May 1977 and the casing desing is presented in the following table:

Hole size	Depth (m)	Casing size	Depth (m)
17 ½"	108	13 3/8"	105
12 ¼"	625	9 5/8"	624
8 ½"	1256	7 5/8"	614-1256

A flow test report indicates low flow rate and production declining with time (few hours). The mass flow rate ranges from 24 to 31 kg/s and the enthalpy is about 1030 kJ/kg. Several injectivity test indicate 1.6 lts/s/kg/cm^{2}g for the Injectivity Index, this index is lower that of other wells in the field.

Within the scope of the Ahuachapan Stabilization Project, CEL is considering drilling new production wells at the south and southeastern areas. The target for the simulation studies is based on the estimation of the production rates of the new wells. In fact we have been using similar Productivity Index to those of other production wells in the field. It is also necessary to analize the reason for the low production rate for well AH-18 to determine if the new wells will require induction.

Again, wellbore simulator HOLA was used for this work but due to the lack of data on production flow rates or flowing profiles, the matching process was carried out using the static profiles considering a normal temperature and pressure drawdown and some discharge data.

An upper production zone at 800m and another one at a depth of 1200 m was used for the simulation, correlating it with the circulation losses during drilling. The Productivity Indexes from the simulation were $0.1E^{-10}$ and $0.1E^{-11}$ m^3 to match with WHP=3 bar-a and 24 kg/s flow rate as measured during a test in Aug. 1984.

If well AH-18 or the new well in this area could maintain a long term discharge and considering the same PI for the required WHP (6 bar-a), to connect the well to the power plant, the simulator indicates the total flow rate will reach 7 kg/s with 12% of dryness. In that situation the feasibility of the operation can not be economical. Figure 9 shows the HOLA results.

Despite the unsuccessful production results from AH-18, its the high measured temperature and the temperature contours suggest an upflow at this area, in this sense a PI of twice that of the production wells in the field was used (e.i. $0.2\ E^{-10}$ m^3).

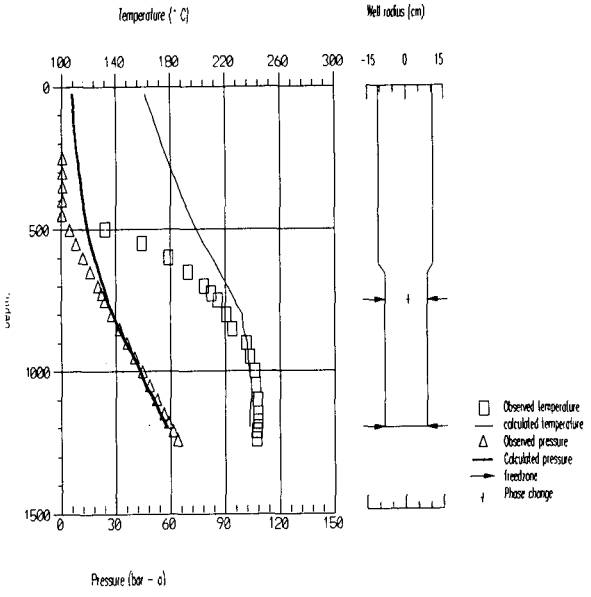

Fig. 9. Simulation results well AH-18, WHP 6 bar-a and equal PI.

The results indicate flow rates of 60 kg/s, 15% dryness and 9 kg/s of steam. The power capacity for each well will reach 3.5 Mwe with 6 bar-a WHP. The wells may not require air induction. The results are shown in the Figure 10.

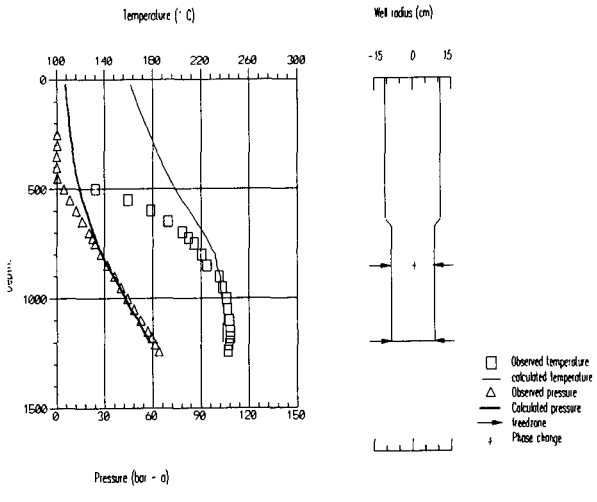

Fig. 10. Simulation results, well AH-18, WHP 6 bar-a and double PI.

CONCLUSIONS

- A wellbore simulator HOLA has been successufully used to estimate the main production characteristics for flowing wells at low cost and time. This simulator represent a very useful tool for the reservoir engineering studies.

- The simulation study for well AH-4_{bis} indicates high probablity of obtaining a good production well with total flow rate close to 40 kg/s, 1250 kJ/kg enthalpy for a WHP of 6 bar-a. The power capacity will reach 7 Mwe with the actual reservoir conditions. If the linner diameter is changed from 9 5/8" to 7 5/8" the production could be reduced to 40% of the total production from the well.

- The new production characteristic of well AH-17 without scaling have been estimated and the liquid phase rate calculated for several well-head conditions. Furthermore, the liquid phase production will be less than 10-5 % of the total mass, therefore in this manner it be difficult to reduce the silica scaling.

- The low production rate of well AH-18 is due to the low surrounding permeability, the high temperature indicates a convective zone nearby, with higher permeability and an upflow area; in the case that higher permeability is found, the WHP will be higher, hence the well will not require induction, and CEL believes the new wells will be good producer.

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