PRESSURE/TEMPERATURE/SPINNER LOGGING METHOD AND INTERPRETATION IN GEOTHERMAL RESERVOIRS UNDER TWO-PHASE CONDITION

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1. INTRODUCTION

Pressure/Temperature/Spinner(P/T/S) logging tool is very effective to obtain the following important parameters of geothermal well. Usually, one static logging, multiple step flow rate production (or injection) loggings and one build-up (or fall-off) logging are carried out as a set logging for each well. It is possible and rather common to analyze some reservoir parameters (depth and flow rate of each feed point, transmissivity, Skin effect, etc.) under one-phase condition.

However, two-phase (liquid and steam) condition sometimes occur in the reservoir. As everybody knows, in this case, it is very difficult to analyze these parameters because in general the approach for analyzing these pressure transient test is based on unboundary, homogeneous, isotropic, and confined reservoir model or the extended model of it.

This paper represents some of the research of two-phase condition analysis which uses two-phase reservoir simulator and two-phase well bore simulator on production.

2. CONCEPT OF CALCULATION

The model consists of both reservoir part (=feed zone) and wellbore part. As reservoir part, we use the TOUGH simulator by Pruess (1987). And as wellbore simulator part, we use the WELFX simulator which is multiple feed point flow model in wellbore by Schroeder(1988).

In Figure 1. the conceptual model is presented. The reservoir model is simple radial flow model but it consists of multiple layers which are sinks or sources of fluid. The wellbore simulator cuts across the center of the radial flow model. At each point of intersection between sink or source element and the wellbore we can calculate enthalpy by the reservoir simulator and input it to the wellbore simulator.

In Figure 2. Block model used by the reservoir simulator for each feed zone is presented. Reservoir part is assumed as follows;

(1) Width of (i) block is calculated by Eq. 1:

di=0.1*sqr(2)**(i-1) .... Eq. 1

(2) Each feed zone consists of horizontal string of 50 blocks.
(3) Each feed zone is connected at (50) block only.
(4) Used relative permeability function is Corey's curves.
(5) Used capillary pressure function is linear function.
(6) Reservoir consists of two horizontal feed zones.
(7) Two feed zones are divided by non permeable horizontal zone which has 50 [m] thickness.
(8) Start condition of production is regarded as the balance condition which calculated in static in long term.

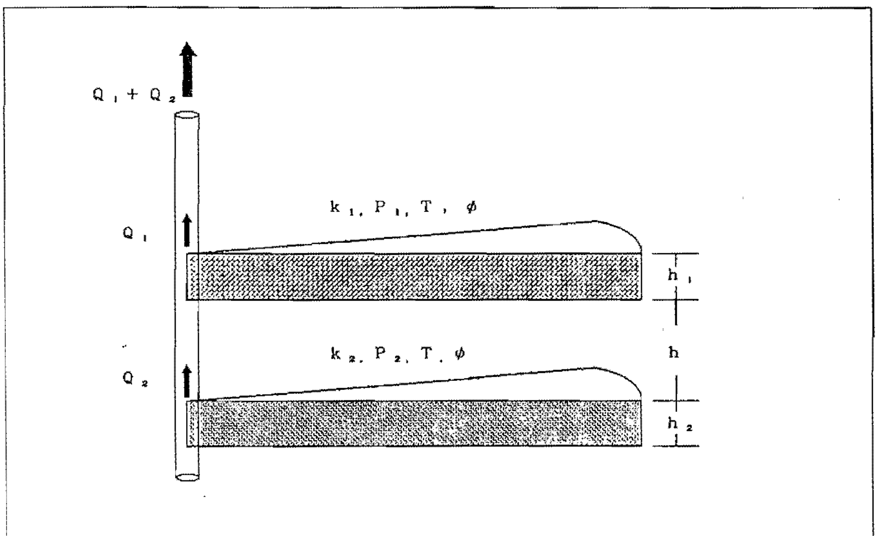

Fig. 1. The conceptual model for dual feed zone (Radial flow model)

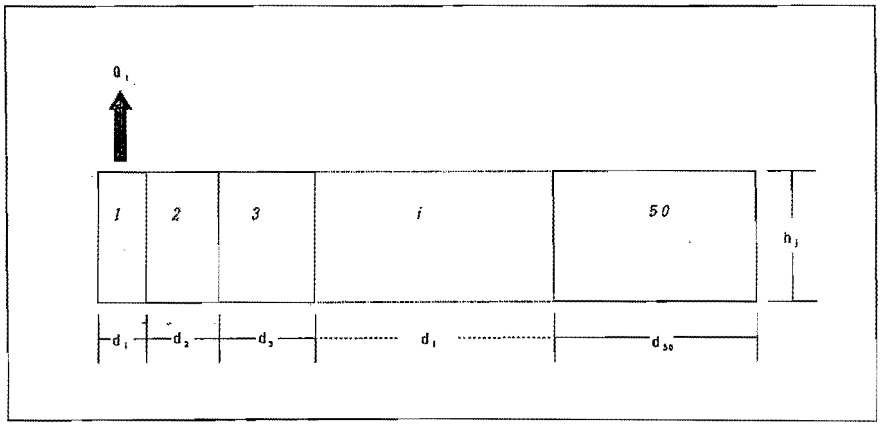

Fig. 2. Grid model each feed zone (IFD method)

Of course it is possible to use other component of relative permeability function and capillary pressure function in obedience to field data. Multiple flow rate production logging must give good experimental function.

In Figure 3. Schematic view of a multiple feedpoint wellbore simulator is presented. This simulator needs flow rate, enthalpy, and depth of each feed point as input data. Wellbore part is assumed as follows;

(1) Well diameter is constant (0.25 [m]).
(2) Wellbore has no heat loss.
(3) Well depth is 1000 [m].
(4) Feed zone consists of two feed points (depth = 1000 , 960 [m]).
(5) Input enthalpy is the value after one day calculated by reservoir simulator.

3. PARAMETERS

In Table 1. the parameter for reservoir part is presented.

Two case of parameter study is carried out in this paper. Flow rate of each feed zone and permeability is changed in case 1, and temperature of q1 is changed in case 2.

Table 1. THE PARAMETER FOR RESERVOIR PART

Parameter	Name	Value
AA 1	feed point 1	-
BB 1	non permeable intermediate zone	-
CC 1	feed point 2	-
Z1	depth of AA 1	960 [m]
Z2	depth of CC 1	1000 [m]
d1	thickness of AA 1	10 [m]
d2	thickness of CC 1	10 [m]
db	thickness of BB 1	50 [m]
q1	flow rate of AA 1	50,100,200 [t/h]
q2	flow rate of CC 1	50,100,200 [t/h]
t1	temperature of q1	285.5 (case 1) [degC] 200. -285.5 (case 2) [degC]
t2	temperature of q2	285.5 [degC]
p1	initial pressure of AA 1	7.0 (case 1) [Mpa] calculate (case 2) [Mpa]
p2	initial pressure of CC 1	7.44 (case 1) [Mpa] 7.0 (case 2) [Mpa]
k1	permeability of AA 1	5.E-13 to 1.E-11 [m^2]
k2	permeability of CC 1	5.E-13 to 1.E-11 [m^2]
phi	porosity	0.2
Rho	density of rocks	2650 [kg/m^3]

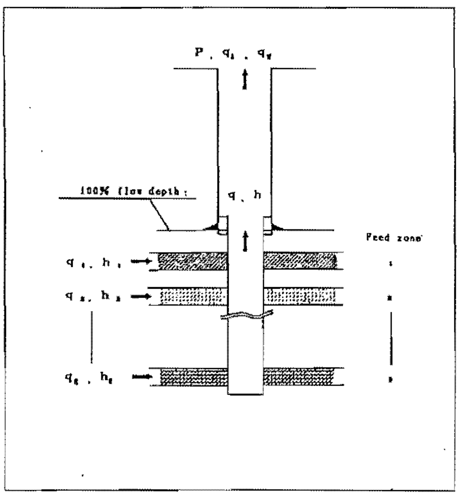

Fig. 3. Schematic view of a multiple feedpoint wellbore

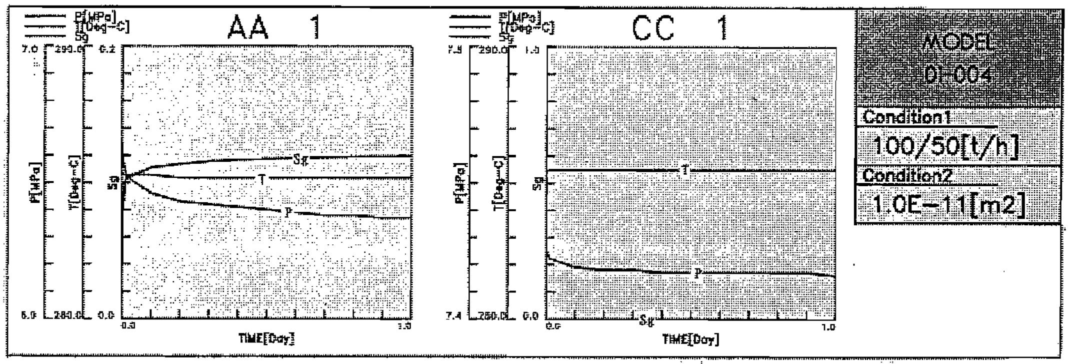

Fig. 4. results of reservoir simulation (Model 01-004)

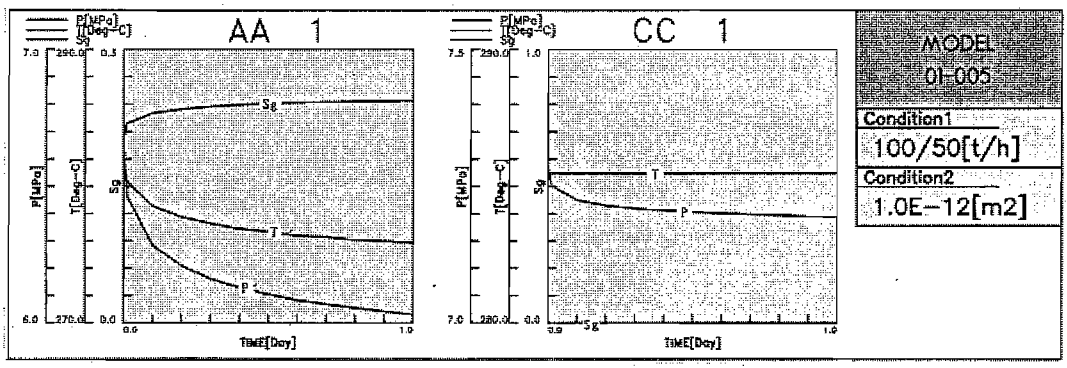

Fig. 5. results of reservoir simulation (Model 01-005)

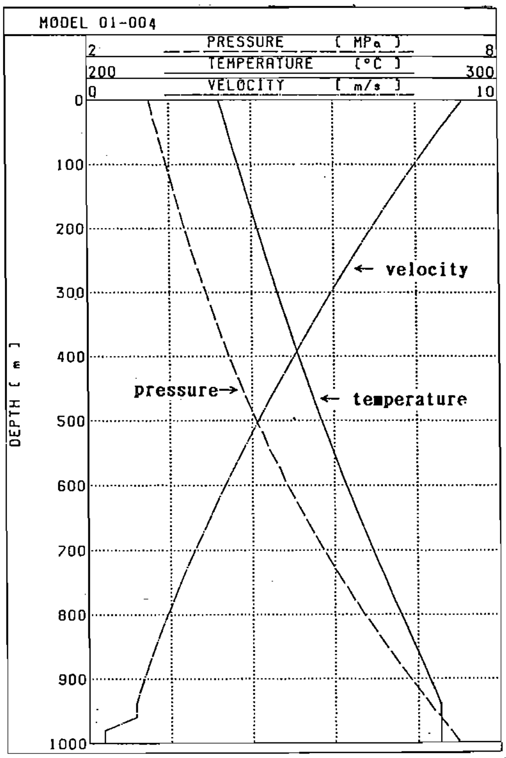

Fig. 6. results of wellbore simulation (Model 01-004)

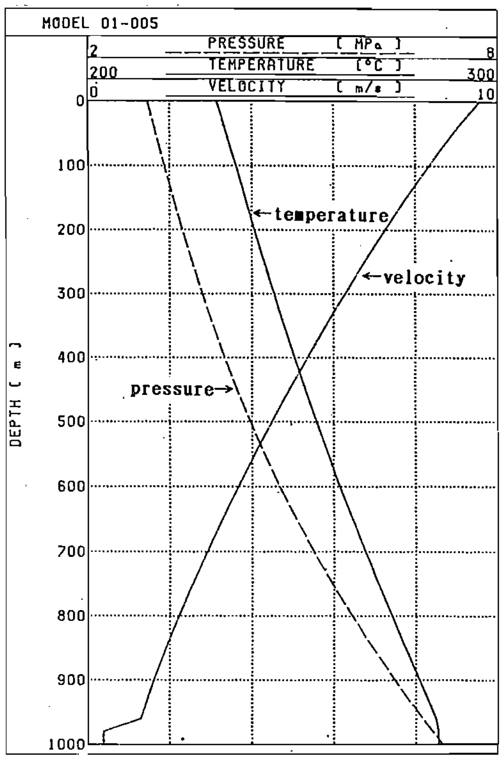

Fig. 7. results of wellbore simulation (Model 01-005)

4. RESULTS

Figure 4. and Figure 5. show some results of reservoir simulation part. In these examples, q1 and q2 were constant values (100 [t/h] and 50 [t/h]) and only permeabilities were changed.

Figure 6. and Figure 7. show the results of wellbore simulation part for Figure 4. and Figure 5.

Figure 8. and Figure 9. show the result in which temperature of q1 is lower than q2. This case means colder fluid is produced at upper feed zone.

These calculations were practiced on Hewlett-Packard 9000/350 32bit computer. The average practical time of each case is approximate 45 minutes.

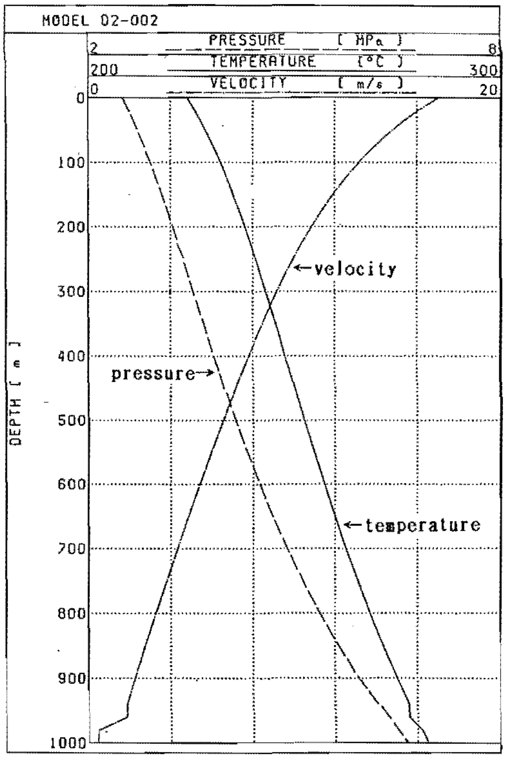

Fig. 9. results of wellbore simulation (Model 02-002)

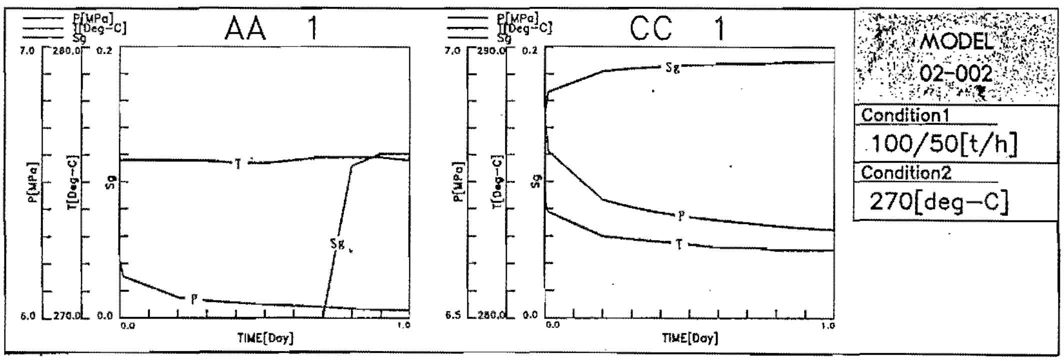

Fig. 8. results of reservoir simulation (Model 02-002)

5. CONCLUSIONS

The result shows the possibility of well testing interpretation under the condition of two phase production. The practical time of computation is enough to use it for interpretation. It must be fit the calculation result to real production P/T/S logging profile.

However, the following points must be paid attention to use it;

(1) Difficulty to select the most suitable relative permeability function.
(2) How to translate Spinner data to fluid velocity ?

In regarding to (1), if it is possible to get the production P/T/S logging profile on many steps of flow rate, the most suitable relative permeability function must be made from these data. Therefore, many steps of rate have to be practiced for production P/T/S logging if two phase condition is appeared into reservoir.

In regarding to (2), we need more experience.