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Production / Re-Injection Optimization in Kutahya-Simav Geothermal Field with Lumped Parameter Modeling

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Abstract
In geothermal reservoir tank modeling is mainly used at the early life of the field when relatively little data is available. Also, the other advantage of tank modeling is that the result is obtained in shorter time during history matching. Because of that reason, tank modeling is used in reservoir which does not have heterogeneous, the fluid in reservoir is not complex and the well doesn't consist of different geometry structure. Mass and energy balance equations are solved on the tanks for making future performance predictions of pressure and temperature. If production data is available, model parameters that best describe the system could be obtained through history matching. In this study, advantages of tank modeling was considered and we have also pointed out a methodology for determining the best model that represents the system. For this purpose, we perform history matching with various models and select the one that matches best the production data and the model that gives the lowest confidence intervals for the model parameters. Effect of temperature is neglected at low temperature geothermal reservoir. Although it is important to make accurate predictions of pressure and temperature, it is more important to make predictions of the uncertainty regarding the pressures and the temperatures. In this study we have used the non-isothermal single tank modelling for performing Kütahya-Simav geothermal field modeling. The scope of the model parameters is determined by using interference test datas. Calibration of model parameter values are realized with JMP statistics program. An interface has been created on computer and field model has been developed using this interface. Model has been revised by defining calibration of the model parameters and uncertainties. After modelling, having been planned the production, changes in pressure and temperature profiles under different type of reinjection scenarios are revealed by taking into consideration that field needs more fluid for city heating in the winter.

Keywords: *Kutahya Simav, geothermal field, tank modeling, model parameters, well tests analysis, interference test.*

1. Introduction
Intensive studies have been carried out by the General Directorate of Mineral Research and Exploration in order to find out geothermal resources of Turkey in recent years and gain them to the economy of the country. Many of the geothermal fields have been brought to the country economy by these studies. The unconscious used of the fields will cause the fields to become inoperable after a certain period of time. The most important point in the operated of these areas is to keep the geothermal field operated in renewable condition. Geothermal fields should be operated in such a production/re-injection optimization that the field is maintained. In this context, correct operation of the geothermal field operated is possible by accurate modeling of the area. With modeling, it is possible to determine how the water level (pressure) and temperature profile will change during the operation of the field and correct production / injection optimization of the field can be made. The fields can be kept renewable with production/re-injection optimization.

Geothermal reservoir modeling is done in the literature in two ways as numerical modeling or tank modeling in general. The working principle of numerical models is based on solving the mass balance and energy balance equations on each cell by dividing the reservoir into cells. In tank models, the reservoir and the aquifer in the geothermal system are represented by tanks. Tank modeling is more preferred because of the complexity of numerical models and the need for detailed field data. Due to the fact that many geothermal fields in our country start to new operation, detailed data needed for numerical models can not be found, so it is preferable to model the fields with tank models.

Geothermal reservoir modeling studies are carried out by solving mass conservation equations and energy

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conservation equations together. The correct determination of the parameters (including reservoir characteristics) needed in solving this equations are important in order to give accurate results in the model to be made. Well tests on geothermal fields are very important for this reason. Parameters including many field characteristics can be estimated by evaluating well test work.

2. Tank Modeling for Geothermal Reservoirs

Whiting and Ramey (1969) tried to determine the reservoir properties using the lumped parameter model. Brigham and Morrow (1974) applied the lumped parameter model in a vapor-dominated system. Bodvarsson (1984) and Pruess (1984) conducted a scattered parameter model study to estimate the future performance of the reservoir in the Krafla geothermal field. Bodvarsson et al. (1986) have carried out a theoretical study on the modeling of geothermal reservoirs. With this study, they discussed different modeling approaches, discussed their advantages and limits. Alkan and Satman (1990) developed the dimensionless parameter model for geothermal reservoirs containing carbon dioxide. Sarak (2004) developed analytical equations for tank models in various configurations for low-temperature geothermal reservoirs. Onur et al. (2008) developed a non-isothermal dimensionless parameter model for liquid-weighted low-temperature geothermal reservoirs. Onur et al. (2008) developed a non-isothermal dimensionless parameter model for liquid-weighted low-temperature geothermal reservoirs. As a next step forward of this study, Tureyen, Onur and Sarak (2009) developed a dimensionless parameter model for non-isothermal liquid weighted geothermal reservoirs.

Tank modeling for determining the reservoir production schedule and increasing production performance is an alternative to numerical modeling in cases where the parameters and data are low. In tank models, reservoir and aquifer are defined as homogeneous tanks. Tank models consist of three main parts: (1) Reservoir, (2) Aquifer and (3) Supply source. The reservoir and the aquifer are represented by homogeneous tanks with average characteristics. The supply source can be connected to any of these tanks (either to the aquifer or the reservoir itself) or to all tanks and represents the constant pressure outer boundary of the system. If the tank model is connected to a source of recharge, this system is called an open system and if not connected it is called a closed system.

The basis of pressure and temperature calculations in tank models is the solution of mass and energy conservation equations for tanks. The tank models are divided into two groups;

Isothermal Tank Models

If only the mass conservation equations are solved on the tanks representing the geothermal system, these models are called isothermal models. If there is recharge, the system is called open model if there is no recharge, the system is called closed model.

Non-Isothermal Tank Models

By solving the energy balance equations together with the mass balance equation, non-isothermal models are obtained. The pressure-temperature behavior of the aquifer and reservoir in the geothermal system can be modeled with this model. Figure 1 shows the generalized of non-isothermal tank model.

Mass and heat convection equations used in tank models (Onur M., v.d., 2008);

$$V_r \frac{d(\rho_w \phi_r)}{dt} + \left[W_p(t) - W_{inj}(t)\right] - \alpha_s[p_i - p(t)] = 0$$

The first term in the mass conservation equation above refers to the mass flow that accumulates in the reservoir, the second term refers to the net production flow and the last term refers to net flow rate,

Heat transport equation;

$$\frac{d}{dt}[(1-\phi_r)V_r\rho_m C_m T + V_r\phi_r\rho_w U_w] - W_{inj}(t)h_{w,inj}(t) + W_p(t)h_{w,p}(t) - \alpha_s[p_i - p(t)]h_{w,s}(t) = 0$$

Here;

V_r	: Reservoir volume (m^3)	$h_{w,s}$	: Recharge water specific enthalpy, kJ/kg
ρ_m	: Density of rock solid part, kg/m^3	$h_{w,inj}$	: Specific enthalpy of injection water, kJ/kg
C_m	: The rock solid part has a specific heat capacity, kJ/(kg °C)	$h_{w,p}$	: Specific enthalpy of water produced, kJ/kg
T	: Temperature, °C		

ϕ_r : Porosity value
ρ_w : Density of geothermal water, kg/m^3
α_s : Amount of recharged water kg/s
W_p : Amount of Production kg/s
U_w : Specific internal energy of geothermal fluid, kJ/kg
W_{inj} : Amount of injection kg/s

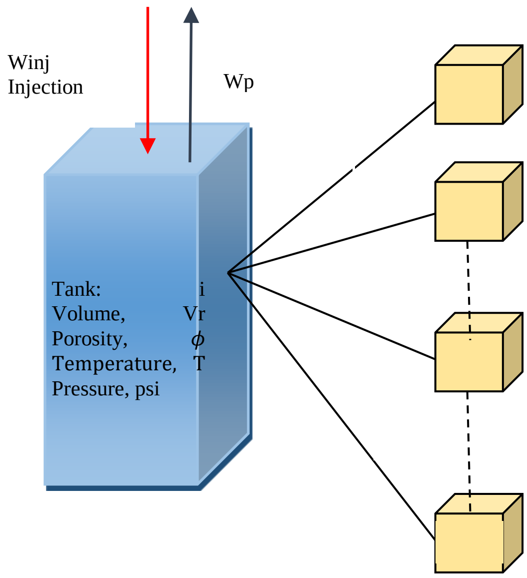

Figure 1. Generalized isothermal model

In the equation; The first term refers to accumulated energy in the fluid and rock, the second term refers to energies entering the injected flow system, another refers to energies drawn from the system due to production fourth term refers to the energy entering the system from the connected tanks.

What is true in the field modeling is the correct determination of the parameters that reflect the characteristics of the field. Correct parameter values can be determined by evaluating the geological, geophysical, drilling and well tests made in the field. The parameter values that can not be determined correctly cause the modeling work to return to the beginning. For this reason, field data should be carefully examined before starting the modeling run.

As the heat conservation and mass conservation equations are solved together in non-isothermal modeling work, the values of the parameters in both equations should be determined before modelling.

1- *Mass conservation equation,*

$$R_1\left(p^{n+1},T^{n+1}\right) = (\rho_w\phi_r)^{n+1} - (\rho_w\phi_r)^n - \frac{\alpha_s \Delta t_{n+1}}{V_r}[p_i - p(t)] + \frac{\Delta t_{n+1}}{V_r}\left(W_p^{\,n+1} - W_{inj}^{n+1}\right) = 0$$

2- *Heat transport equation,*

$$R_2\left(p^{n+1},T^{n+1}\right) = (1-\phi_i)\rho_m C_m\left(T^{n+1} - T^n\right) + \left[\phi_r^{n+1}\rho_w^{n+1}U_w^{n+1} - \phi_r^n\rho_w U_w\right] - \frac{\Delta t_{n+1}}{V_r}W_{inj}^{n+1}h_{w,inj} - \alpha_s\frac{\Delta t_{n+1}}{V_r}\left[p_i - p^{n+1}\right]h_{w,s} + \frac{\Delta t_{n+1}}{V_r}W_p^{n+1}h_{w,p}^{n+1}$$

3- *Change of porosity with pressure and temperature,*

$$\phi(p,T) = \phi_i[1 + c_r(p(t) - p_0) - \beta_r(T(t) - T_0)]$$

If the non-isothermal model equations and the pressure-temperature change equation of the porosity are examined, we can collect the model equation parameters in 3 groups. These include (i) reservoir rock properties, (ii) fluid characteristics, and (iii) field production / recharge and re-injection information.
Since the mass and energy equations are nonlinear differential equations, it is necessary to solve them together with the completely closed Newton-Raphson method (Burden and Faires, 1989). Pressure (p) and temperature (T) are considered as primary variables in the analysis. The equations are solved with the following algorithm as the function of time for these variables.

The vector, $w^{n+1,k}$, containing the pressure and temperature at the k iteration step of the Newton-Raphson method is defined as follows:

$$W^{n+1,k} = \begin{bmatrix} W_1^{n+1,k} \\ W_2^{n+1,k} \end{bmatrix} = \begin{bmatrix} p^{n+1,k} \\ T^{n+1,k} \end{bmatrix}$$

With a given initial ($w^{n+1,0}$, k = 0, 1, 2, ...) estimate, the following matrix vector equation is solved by the Newton-Raphson method:

$$\boldsymbol{J}^{n+1,k} \delta w^{n+1,k+1} = -\boldsymbol{R}^{n+1,k}$$

Where J represents the calculated Jacobian matrix of the solution vector w^{n+1}, k in the previous iteration step.

$$J^{n+1,k} = \begin{bmatrix} \frac{\partial R_1}{\partial p^{n+1}} & \frac{\partial R_1}{\partial T^{n+1}} \\ \frac{\partial R_2}{\partial p^{n+1}} & \frac{\partial R_2}{\partial T^{n+1}} \end{bmatrix} \quad R^{n+1,k} = \begin{bmatrix} R_1 \\ R_2 \end{bmatrix} \quad so \quad \begin{vmatrix} \frac{\partial R_1}{\partial p^{n+1}} & \frac{\partial R_1}{\partial T^{n+1}} \\ \frac{\partial R_2}{\partial p^{n+1}} & \frac{\partial R_2}{\partial T^{n+1}} \end{vmatrix} \begin{vmatrix} \Delta P^{n+1} \\ \Delta T^{n+1} \end{vmatrix} = - \begin{vmatrix} R_1 \\ R_2 \end{vmatrix}$$

3. Kutahya-Simav-Eynal Geothermal Fields

The Simav Geothermal field is located about 4-5 km north of Simav city center (figure 2). The sources on the field, which have a large number of hot water sources, are mainly concentrated in 2 areas. From these areas, Eynal District is located about 4 km north of Simav city center. Çitgöl sources in Çitgöl-Naşa Region are located about 3 km west of Eynal and Naşa sources are 3 km north-west.

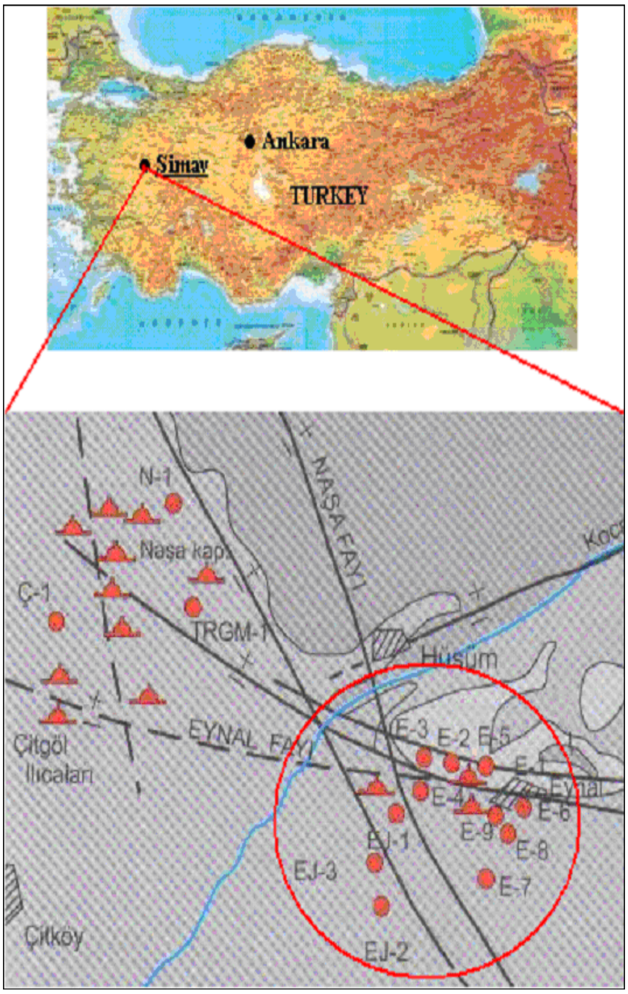

Figure 2: Kütahya-Simav settlement

Paleozoic metamorphic rocks are located at the base of the rock strata in the area. The rocks form the mountains that border the graben on both sides, and outcrop frequently in these mountains. These rocks are overlain by volcanic rocks and lake sediments of Miocene that were deposited in the graben along a NNE-SSW axis and formed in relation to those grabens. These formations appear on the Simav horst to the south of the graben as well as on ridges of the arm to the north of the graben, which has risen to a lower altitude. These are followed by younger formations which formed together with the Simav graben. These are spread out over the graben interior areas, which have been downthrown significantly compared with the horsts on both sides of the graben. Based on the existing wells drilled in the area, the fractured reservoir rocks producing hot fluids in the field largely consist of Naşa Basalt, Simav metamorphics and Mesozoic limestones, while the cap rock consists of Tertiary strata of volcano-sedimentary rock (figure 3) *(Olayinka, 2013)* .

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The Simav Geothermal Field is located on the NE side of the Simav Plain. Covering an area of 70 km^2, the elevation of the plain is about 780 m. By contrast, Mount Simav in the south of the plain reaches 1780 m. The Simav Geothermal Field is located on the east side of the plain, which is separated from this mountain by a steep and high slope. (Öngür, 2004).

The depths of the wells in the Simav area are between 65.8 m (E-1) and 958 m (EJ-2). The measured well bottom temperatures range from 105.1°C (Ç-1) to 162.470C (EJ-1). The units encountered as reservoir rocks in wells outside the E-1 and Ç-1 wells are the Simav Metamorphics. Table 1 shows depth and temperature information of wells opened in Eynal.

Comprehensive test work carried out in the field was carried out in 2006. In these tests, static-dynamic temperature and pressure, pressure reduction, pressure rise, injection, production and interference tests were performedin the wells.

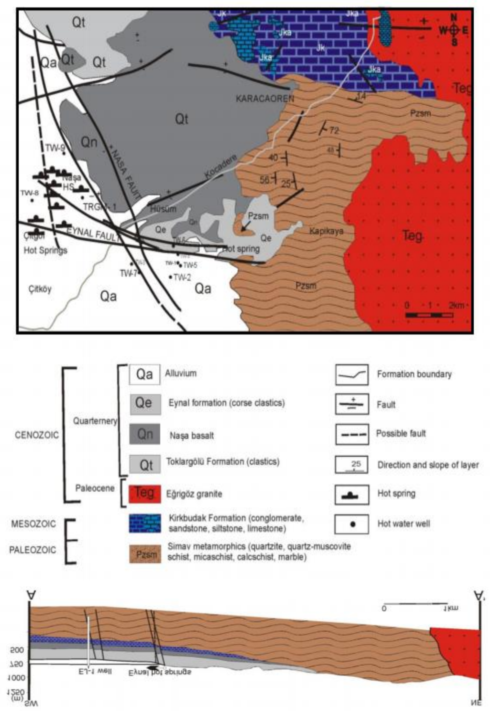

Figure 3: Simav Geothermal Field Cross-section (Olayinka, 2013)

4. Kütahya-Simav Geothermal Field Modeling

Table 1: Drilling Wells of Kütahya-Simav Eynal Region and Well Temperature Ratings

Well	Drilling Date	Depth (m)	Flow (kg/s)	Temperature °C
E-1	1985	65	14	142 (WB
E-2	1985	149	55	158 (WB)
E-3	1985	150	50	149 (WB)
E-4	1994	220	1	98
E-5	1995	300	6	97
E-6	1994	169	50	157 (WB)
E-7	1997	475	0.25	52
E-8	1997	205	80	92
E-9	2004	208	60	98
E-10	2005	288	90	108
E-11	2005	502	35	99
E-13	2006	241	35	150
EJ-1	1990	725	72	162 (WB)
EJ-2	1990	958	1	157
EJ-3	1997	424	50	93

Table-2: E-6 Production Values

Date	WHP (bar)	Q (t/h)
7.17.06 16:42	3,7	135,9
7.21.06 11:52	3,6	118,9
7.21.06 12:07	3,75	110,7
7.28.06 13:55	3,8	45,0
7.31.06 13:12		0,0

Table 3: E-10 Production Values

Date	WHP (psi)	Q (t/h)
7.18.06 18:00	53	149,1
7.20.06 8:00	53	145,5
7.24.06 18:00	53	142,0
7.27.06 23:00	52	140,2
7.30.06 16:48		0,0

The modeling of the Kütahya-Simav geothermal field has been carried out through the interference test data carried out on site in the context of comprehensive test work. At the beginning of the 15-day interference test, only the E-6 well was opened on July 17, 2006 at 135.9 t/h, and gradually decreased and closed. In the E-10 well, 149.1 t/h start production was started on 18.07.2006 after 1 day from the E-6 well and gradually decreased and closed.

Fluid production was performed from E-6 and E-10 wells (figure-4) and pressure variation was observed in E-8 well. Figure 5 shows the change in pressure in the E-8 well corresponding to total production.

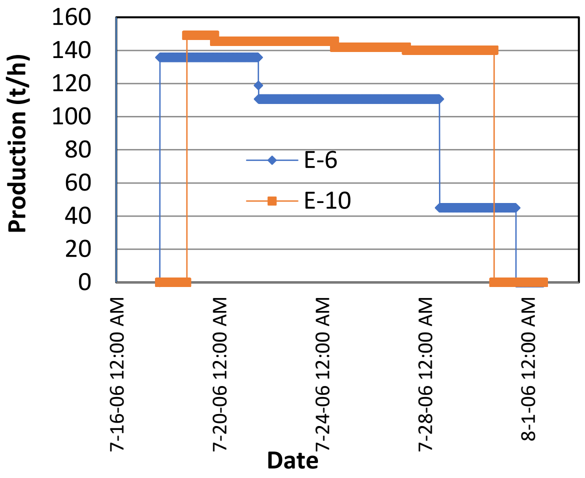

Figure 4: Production Status of E- 6 and E-10 Wells

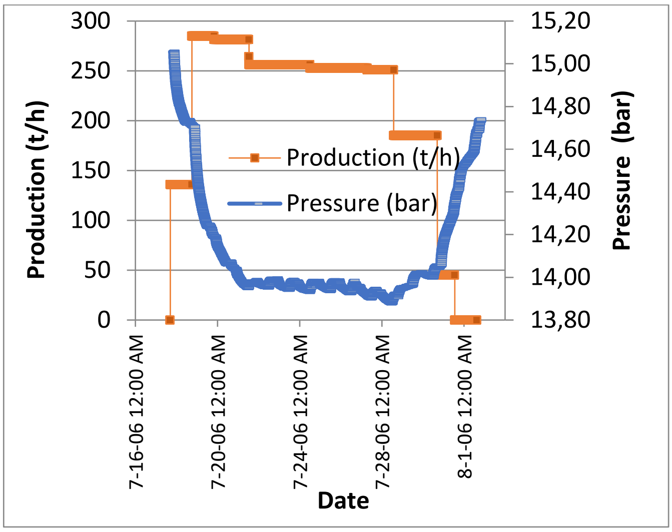

Figure 5: E-8 İnterference Test

Model parameter initial values (Toraman S.,2016); Specific fluid properties (ρw), specific internal energy (Uw), specific enthalpy of produced water (hw, p), specific enthalpy of injected water (hw, inj), specific enthalpy (hw, s) and values of the recharge water's spesific entalpy are based on the fluid properties of the steam table. (Fluid temperature: 163 °C, Average reservoir pressure: 20 bar, temperature of recharge water: 150 °C, temperature of injected water: 60 °C.)

The rock solid part density (ρm) and specific heat capacity (Cm) cover the average values of the geological, geophysical or drilling studies and the reservoir zone of the site, and the average values are determined by examining the geophysical logs from the wells. The reservoir unit of Kütahya-Simav is Simav metamorphic rocks consisting of gray brown colored quartzite, quartz-muscovite schist, micaschist, muscovite-chlorite schist, calcschist and biotite schist. When the geophysical logs from the wells were examined, it was determined that the density of reservoir rock solid part of Kütahya Simav could be between 2.400-2.800 kg / m^3 and the specific heat capacity could be 700-1000 (J / kg °C). In the model, the initial value of density was assumed to be 2,500 kg / m^3, and the specific intrinsic energy value was accepted as 800 (J / kg °C).

Fluid temperature, pressure, reservoir coarse volume, nutrition index, injection index, total compressibility and porosity values were calculated by examining well test runs. According to this, model initial values;

Table 4: Model Initial Values.

Model Parameters	***Unit***	***Value***
Vr: Reservoir volume	(m^3)	$1.0*10^9$-$1.0*10^{10}$
ρ_m: Density of rock solid part	kg/m^3	2500
Cm: Specific heat capacity of the solid portion of the rock	J/(kg °C)	800
T(i): Fluid temperature	°C	162,20
P(i): initial pressure	bar	15,051
ϕ : porosity value	%	$1.91*10^{-7}$/Cr+$1.14*10^{-5}$
ρw : fluid density	kg/m^3	905,31
Uw: Specific internal energy of the fluid	kJ/kg	687,19
hw,s: Specific enthalpy of recharge water	kJ/kg	632,27
hw,inj: Specific enthalpy of injected water	kJ/kg	251,56
hw,p: Specific enthalpy of the produced fluid	kJ/kg	689,39
C_r: Rock compressibility under constant temperature	1/bar	ϕ'ye bağlı
βr: porosity and thermal expansion / contraction coefficient under constant pressure	1/°C	0
αs: Recharge index	m^3/s	0.063

In order to solve the mass and heat transfer equations with completely closed Newton raphson method, an interface has been created in which the parameter values can be easily changed and the relationship between model pressure values and actual pressure values can be seen. With this (figure-6) interface created, the model parameter values were changed to try to get the best model-true pressure compliance. Modifications to the model initial parameters have reached 96% of model / actual pressure data compliance.

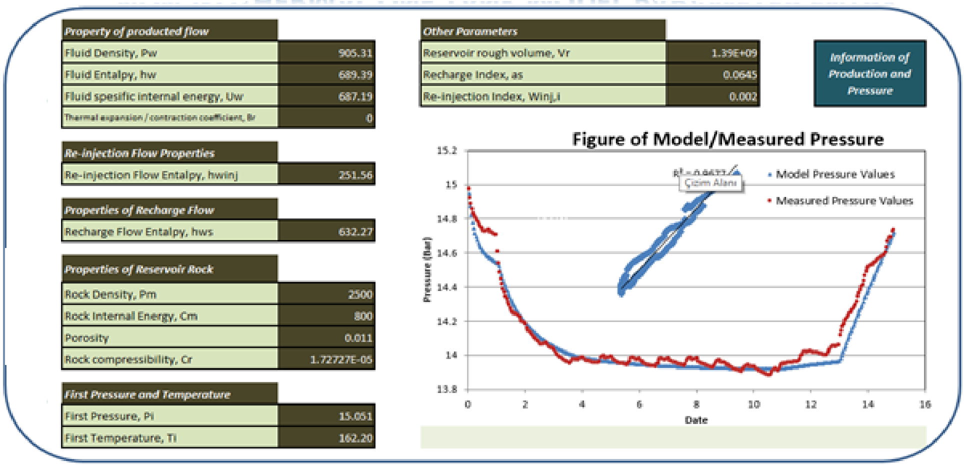

Figure 6: Interface of data entry

After this step, parameter estimation with nonlinear regression was performed to calibrate the model parameter values. The nonlinear parameter estimation was performed by using JMP 10.0.0 (demo) packet program (figure 7).

As a result of the calibrated parameter values, the relationship between the model pressure values and the observation pressure values is examined and the correlation between the data is 99% and the RMSE value is 0,00025 (figure 8).

Nonlinear regression predicted parameter values and wastes are processed in the system. Model / Actual pressure graph figure 9 shows the model parameter values as in table-5.

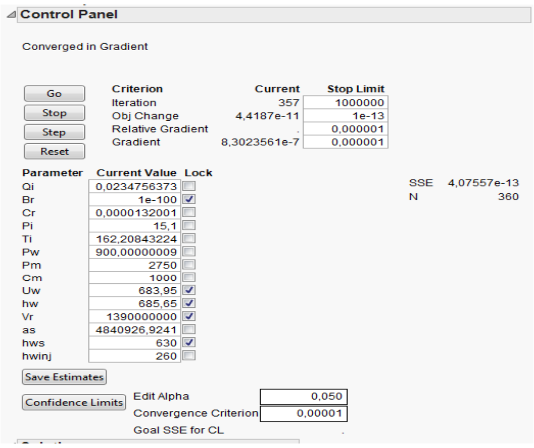

Figure 7: Nonlinear regression analysis

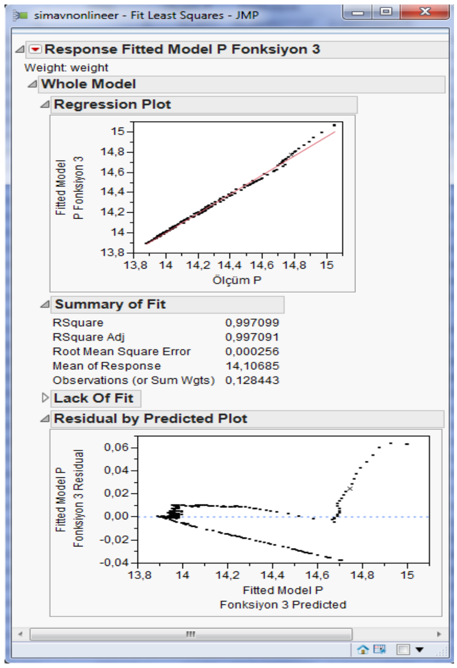

Figure 8: Fit Model

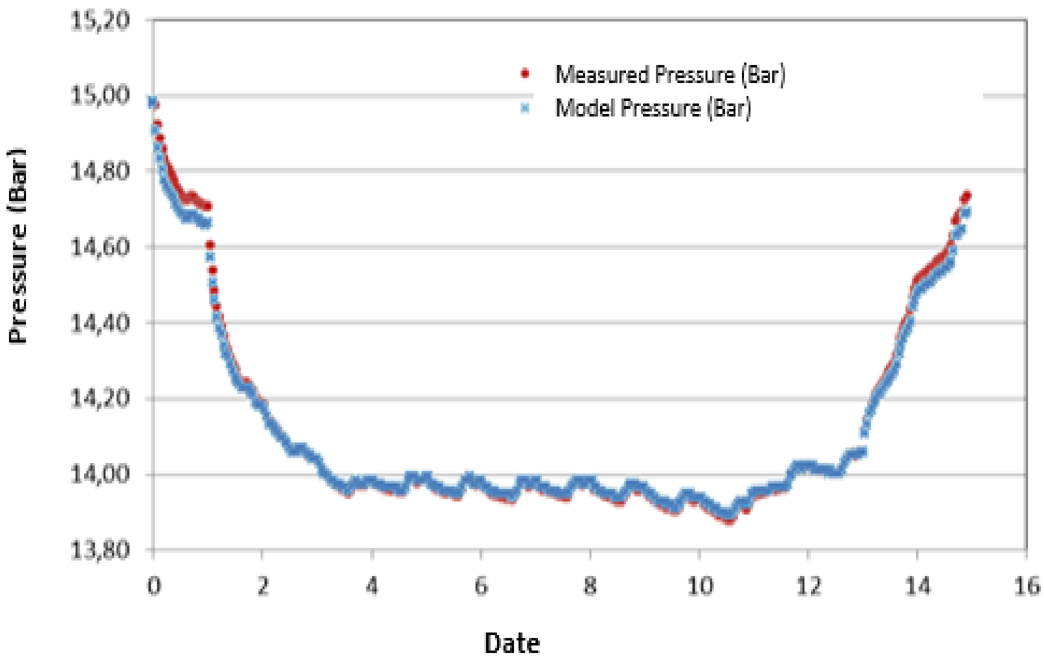

Figure 9: Model / Mesaured Pressure

Table 5: Calibrated Model Parameter Values

Model Parameters	***Birim***	***Değeri***
Vr: Reservoir volume	(m^3)	$1{,}39 * 10^9$
ρ_m: Density of rock solid part	kg/m^3	2750
Cm: Specific heat capacity of the solid portion of the rock	J/(kg ºC)	1.000
T(i): Fluid temperature	ºC	162,2084
P(i): initial pressure	bar	15,10
ϕ : porosity value	%	2,3475
ρw : fluid density	kg/m^3	900,00
Uw: Specific internal energy of the fluid	kJ/kg	683,95
hw,s: Specific enthalpy of recharge water	kJ/kg	630,00
hw,inj: Specific enthalpy of injected water	kJ/kg	260,00
hw,p: Specific enthalpy of the produced fluid	kJ/kg	685,65
C_r: Rock compressibility under constant temperature	1/bar	$1{,}32001 * 10^{-5}$
βr: porosity and thermal expansion / contraction coefficient under constant pressure	1/ºC	0
αs: Recharge index	m^3/s	0.0619

5. Production / Re-Injection Optimization of Kütahya-Simav Geothermal Field (Toraman S., 2016)

5.1. Annual Production Assessment

In order to determine the annual pressure and temperature changes of the Kütahya-Simav Geothermal Field, the model is run within the production schedule of Figure 10. The field was operated on 338 days with an average production of 227.94 t / h (5.470.56 tons / day) and 27 days without production. In comparison to total 1,8E + 06 tons of fluid production, a 0,334 bar pressure drop with 0% re-injection and a temperature change of -0.00034ºC (feeding water temperature 150 ºC) were observed (table 6).

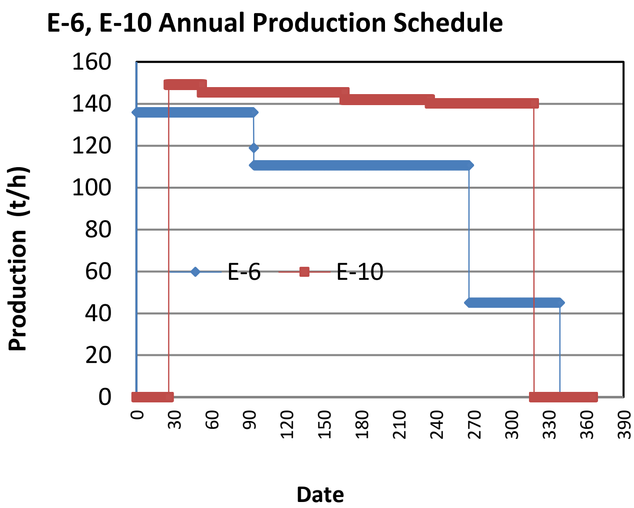

Figure 10: Annual Production Planning (Scenario-0)

Table 6: Pressure and Temperature Changes

Field Assessment (Production =338 days /average 227.94 t / h Production off= 27 days)	
Re-injection ratio (% WP)	0
Pressure change (bar) (P_{end} -P_{first})	-0,334
Temperature change (ºC) (T_{end} -T_{first})	-0,00034
Production (t/year)	1,85E+06

In order to be able to design the production plan more flexibly, a production planning module has been added so that production planning can be made according to the monthly requirement in terms of program t/h. In the winter months, annual field production planning (scenario-1) was taken considering the city heating (Figure 11). All wells that can be manufactured are included in the system.

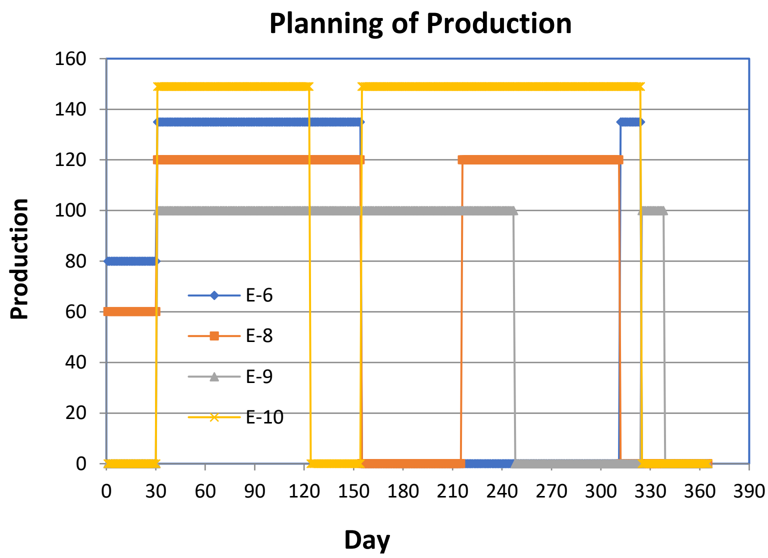

Figure 11: Annual Production Planning (Scenario-1)

The changes in field pressure and temperature profiles were investigated in the case of figure 13 production plan (scenario-1) where the field was 338 days production, 27 days non production and non re-injection. A total of 2,54E + 06 tonnes of fluid was produced within an average production of 312.84 t / h (7.508 t / day). The pressure difference in the chamber was -0.464 bar and the temperature change was -0.00047 ºC (table 7).

In order to investigate the behavior of the field by re-injection addition, it has been investigated whether the changes in the field and it can be maintained in the renewable form when re-injecting 10%, 25%, 35%, 45% and 48% of the amount of fluid produced (Re-injected water temperature 60 ºC). 48% of the produced fluid must be re-injected in Scenario-1 production planning in order to ensure that the field reaches initial pressure in the event of a 41.71 kg / s fluid backpressure in a 48% re-injection scenario and thus the field remains renewable. (figure 12,13,14)

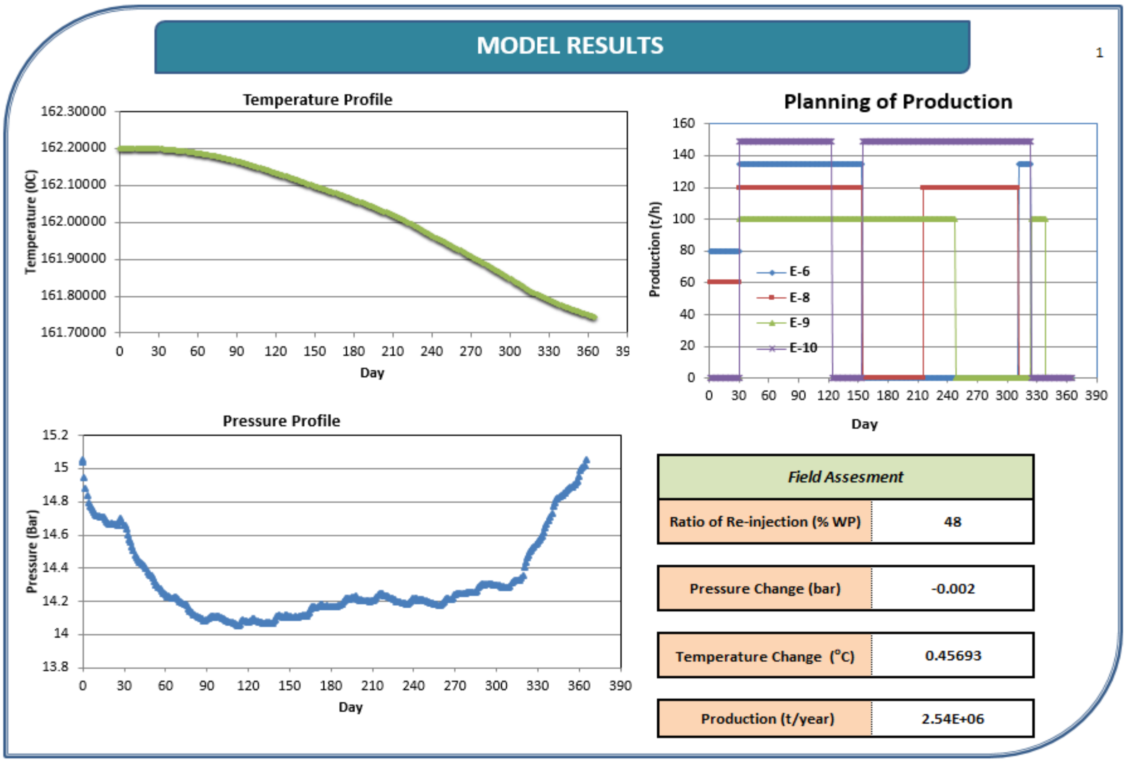

Figure 12: Scenario-1 Production Planning Model Results

Table 7: Scenario-1 Production Planning Status / Re-injection Analysis.

	Re-enjeksiyon Value (kg/s)	*Pressure Change (Bar)*	*Temperature Change (°C)*
%0 Re-injection	*0*	*0,464*	*0,00047*
% 10 Re-injection	*8,69*	*0,271*	*0,0914*
% 25 Re-injection	*21,72*	*0,135*	*0,2356*
% 35 Re-injection	*30,41*	*0,065*	*0,33181*
% 45 Re-injection	*39,1*	*0,011*	*0,42805*
% 48 R-injection	*41,71*	*-0,002*	*0,45693*

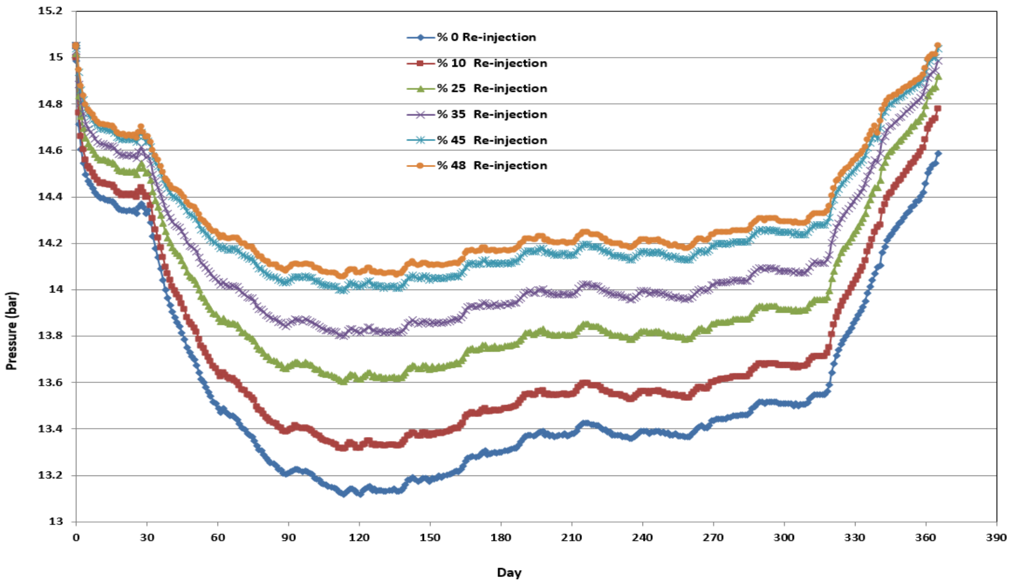

Figure 13: Scenario-1 Re-injection Alternative Equivalent Field Pressure Changes

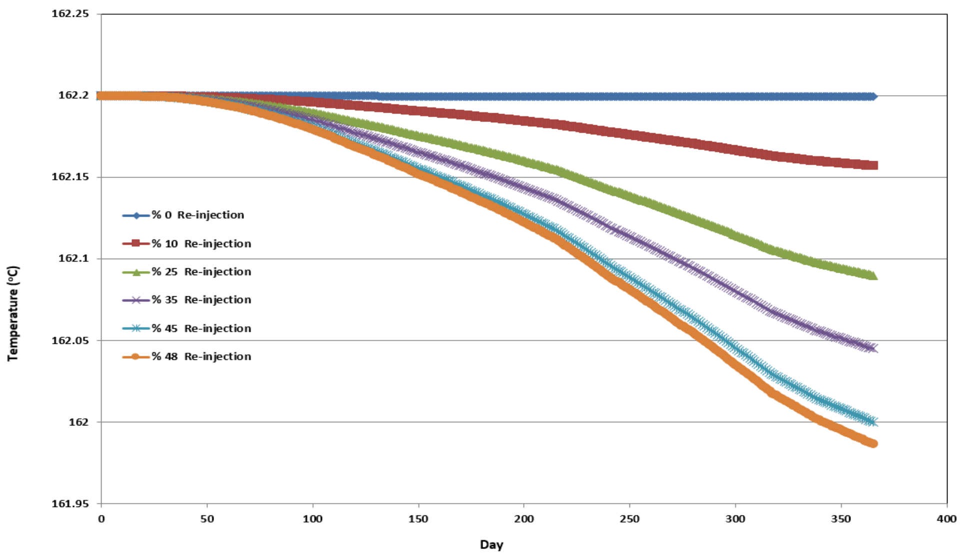

Figure 14: Temperature Variation compared to the reinjection rate

Scenario 2; 338 days 500 tons / h of fluid production and 27 days of non-production field pressure, temperature and re-injection rate determination. In scenario 2, if the yearly 4,06E + 06 tonnes of fluid were not re-injected, the pressure loss in the field was -0,727 bar, the temperature change was -0,00074 ºC. It has been determined that the field will be in a renewable form if re-injected with 46% produced fluid. In the case of 46% re-injection (63,94 kg / s re-injection), the pressure difference will be 0.002 bar and the temperature difference will be -0,326 ºC. Field profile information for all scenarios is as in table 8.

Figure 15 shows the change in the field temperature with re-injection and figure 16 shows the change in pressure when there is no future re-injection of the field with the production scenario.

Table 8: Field temperature-pressure variations for production and re-injection scenarios

Scenarios	***Production (t/h)***	***Re-injection (kg/s)***	***Temperature Difference °C/Year***	***Pressure Difference (bar/Year)***
Scenario-0	*227 ton/h*	0	-0,00034	-0,334
	227 ton/h	29,76 kg/s	-0,326	0,001
Scenario-1	312,84 t/h	0	-0,00047	-0,464
	312,84 t/h	41,71 kg/s	-0,456	0,002
Scenario-2	500 t/h	0	-0,00074	-0,727
	500 t/h	63,94 kg/s	-0,698	0,002

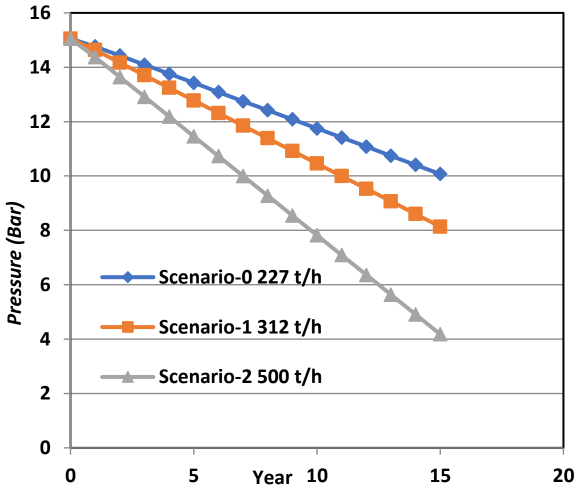

Figure 15: Annual Change in Pressure with Production Scenario (Re-injection = 0)

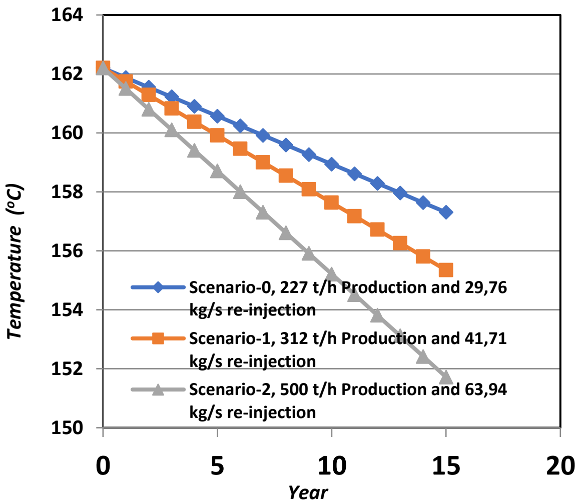

Figure 16: Annual temperature change in field with production and re-injection scenarios

6. Conclusions

Tank modeling involves isothermal and non-isothermal flow hypothetical models and describes only the pressure or water level behavior of the reservoir in isothermal models. Whereas in non-isothermal models, both pressure and temperature behavior can be defined. For this reason, in our study, the non-isothermal model was chosen so that the distribution of the pressure and temperature profile of the field can be determined.

The non-isothermal flow model is obtained by solving the mass conservation equation and the heat transport equation together. Since the mass and energy equations are nonlinear differential equations, they must be solved together with a completely closed Newton-Raphson iteration method. After this analysis, the reservoir parameters are calibrated by calibrating with the data obtained from the field data for calibrating the field parameters. SAS INSTITUTE INC JMP 10 (demo) statistical package program was used to calibrate the parameters in our work. The program was calibrated using the non-linear regression module to calibrate the model parameter values. Accompanying measurement data with nonisothermal flow model can be done with both pressure and temperature data together or only with pressure and temperature data only.

Model uncertainties are also determined from the model by calibrating the parameters. Modeling is terminated by including calibrated model parameters and uncertainties into the system.

Forward performance estimates of geothermal systems include a four-stage process.

a) Sufficient and reliable collection of field data in the creation of models
b) Modeling with this data and calibrating this model,
c) With model calibration, uncertainties between measurement and model should be added to the model,
d) The system is operated under various production / re-injection scenarios with calibrated model.

In this context, a model has been created considering the interference test data realized in Kütahya-Simav geothermal field. Model parameters are calibrated and uncertainties are defined. In order to include the re-injection scenarios in the operation of the system, a model was created with the addition of 0.002 m3 / s re-injection.

The model has been made yearly in order to show how the annual production corresponds to the pressure behavior of the field. Annual production planning was then carried out considering the need for more fluid due to urban heating in the winter months, and pressure and temperature changes in the field were investigated. A total of 2,537,798 tons of fluid was produced in an average of 312.84 t / h production plan. The pressure difference against the planned production amount is 0.464 bar and the temperature difference is 0.00047 ^{o}C. No reenjection was done at this stage.

In the case of re-injecting 10%, 25%, 35%, 45% and 48% of the amount of fluid produced to investigate the behavior of the field by re-injection addition, the changes in the field were investigated. In the case of 48% re-injection, it was observed that the difference in pressure was 0.002 at -0.45693 ^{o}C. If the annual production of 2,5E + 06 tons of fluid and the re-injection of 1,2E + 06 tonnes of fluid are in place, the field is renewable.

2. Scenario, average production of 500 tons / h for 338 days was examined. In case of annual 4,06E + 06 tons of fluid production and no re-injection, the pressure loss on the field was -0,727 bar and the temperature change was -0,00074 ^{o}C. It has been determined that if the amount of fluid produced in the field is re-injected at 46%, it will be renewable. In the case of 46% re-injection, the temperature difference was -0.69879 ^{o}C.

When the re-injection fluid enthalpy is included in the program as 260 kJ / kg (60 ^{o}C), it is seen that as the amount of re-injection increases, the area cooling increases. For this reason, the re-injection point should be determined correctly. The re-injected fluid should be in contact with the heating rock for a sufficient period of time and should undergo sufficient chemical reaction.

In order to study the effect of the re-injected fluid temperature on the field temperature profile, the temperature of the fluid re-injected into the system (63,94 kg / s re-injection during production) was entered as 50, 60, 70 ^{o}C. Annual changes in temperature in the field will be -0.85, -0.69 and -0.58, respectively.

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