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EXPLOITABLE CAPACITY OF HIGH TEMPERATURE RESERVOIR OF YANG-YI-XAING GEOTHERMAL FIELD OF CHINA

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Abstract

Ying-Yi-Xiang high temperature geothermal filed is located in Tibet of China with the absolutely altitude of 4550-5050m.The general area is near 11km^2.There are 28 exploring well have been drilled, total drilling depth is over 10000m.Lithological characteristic of the reservoir is fractured granite. The highest well head temperature is 207ºC . Shut in well head pressure is 2.8-9.4 kg/cm^2. Total flow rate of the whole well is 772-8970t/d, with in the steam quantity of 82.2-2410t/d. Two well carried out injection test. 7 single wells carried out flowing test. One group well carried out interference well test. Long term reservoir well test with 4 wells lasted for 30 days. Using mass and heat transport model, fitting different measured data collected from geothermal filed, optimized parameters, planned 3 extraction scheme. Though calculation in large quantity, find specially curve for exploitable capacity. Final assessment and predict exploitable capacity of yiang-yi-xiang geothermal reservoir is 3.01x10^{4}t/d continuously developing for 30 years, controlling reservoir pressure draw down is 0.15x10^{7}pa. See **figure 1.**

1. Introduction of reservoir characteristic

1.1 General information

Yang-yi-iang geothermal filed is located in the west of yiang-yi-xiang village, where belongs to the ji-da town of dang-xiong county seat of the Tibet. Through 10 years exploration exploitation, it has been definite, that the total area of the field is 10.749 km^2 , with in the high temperature sub-area (>150ºC) is 1.595 km^2 with the code name A+B, The high temperature area is divided into two section by fracture F $_9$.The South part is A, while the north part is B. the middle temperature sub-area(90-150ºC) is 3.229 km^2 with the code name C, the low temperature sub-area (25-90ºC)is 1.595 km^2 with the code name D.

Compare with the other geothermal filed of the Tibet, this geothermal filed has high temperature, pressure, and flow rate. The best feature of the geothermal fluid is without scaling problem at well head. The maximum thickness of the cap rock is 625m,while the minimum thickness of the cap rock is 110m.

In the high temperature area the thickness of the cap rock is 200-360m. Components of the cap rock is very complicated, upper part is sand- coglomirate , semi-sand ,semi-clay, clay etc, lower part is trachyandensite, trachyte, tuff with volcanic breecia etc. Below the cap rock is formation of reservoir that main lithological characteristic is porphyry-granite and granite- porphyry which has been remarkable hydrotherrmal metamorphism. Lithological structure is in tattered, and is very fractured. The high temperature area exposed thickness of the reservoir is 63-703m. The fluid temperature is controlled by the F$_9$ fracture, Fluid temperature of the A sub area is 195-207ºC, that is higher then the B sub area with the fluid temperature of 165-175ºC. The hidden feature of the reservoir in the high temperature sub area see **table 1**.

1.3 Anomaly pressure gradient

There are anomaly high temperature gradient appeared in the three wells (zk200, zk203, zk208), the three wells is just located near the cross of the F1 and F2 fracture .It shows that the fracture is hot fluid passageway . see **table 2**.

2. Well test and hydro geological parameters

In order to find out condition of the well, flow capacity of the well , hydro geological parameters of formation etc, there are several kind of the well test have been carried out in the filed. One is the step flowing test from 4 wells, see **table 3**. The other is interference well test , No well 208 is extracting well ,the other 8 wells are observation wells see **table 4.** The third one is one group long term flowing test ,this kind of the test lasted for 30 days ,when the test stopped immediately measured data, see **table 5**. Though different kind well test, the main hydro geological parameter have been calculated see **table 6.**

3. Production capacity of the reservoir

3.1 Mass and energy balance equations
According to mass equilibrium law.consider a fixed control volume with surface area A and pointing unite normal vector n, then consideration of mass equation

$$\frac{d}{dt} \int_V Q_m \, dv = - \int_A n \cdot F_m \, d_A + \int_V q_m \, dv \quad (1)$$

In the equation (1)

Q_m — mass flux per volume of the reservoir *(kg/m^3)*
F_m — mass flux vector *(kg/m^2)*
q_m — mass, per volume of the reservoir ,with drawn or injected by well *(kg/m^3)*

Since the control volume is fixed the divergence theorem the surface integral on the right side can be transformed into a volume integral. Then equation (1) becomes

$$\int_V \frac{dQ_m}{dt} \, dv = - \int_V V \cdot F_m \, dv + \int_v q_m \, dv \quad (2)$$

Since V is an arbitrary control volume the integrand must equate, that is

$$\frac{dQ_m}{dt} = -V \cdot F_m + q_m \quad (3)$$

And energy equation can be derived in the same way.

3.2 Production capacity of the reservoir

Solve above mass and heat equations by using numerical solution method, design three long term production scheme, see **table 7**,then predict pressure draw down of each scheme for nearly 20-28 years. The pressure draw down of each production scheme see **figure2, figure3, figure4**..Next step is calculating the exactly pressure draw down for 30 years., through regression analysis method. Using regression analysis method for tree scheme of 30 year’s production again , final find out the reservoir specially line, see figure 4.From this specially line we can known that the capacity of the reservoir is 383l/s($3.31.10^4$ t/d), controlling the pressure draw down as $0.15.10^7$ pa. See **figure5.**

References

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Table 1 Reservoir characteristic of the well in A and B sub area

Well No.	Depth of the well (m)	Altitude of water level (m)	top/bottom altitude of the well (m)	Top depth of the Reservoir (m)	Top altitude of Reservoir (m)	Reservoir thickness (m)
ZK200	403.48	4729.25	4638.21/4031.99	260.00	4378.21	346.22
ZK203	386.00	4738.90	4657.10/4271.10	290.00	4367.10	96.00
ZK290	905.41	4711.57	4619.04/3713.63	350.00	4269.04	555.41
ZK207	703.54	4719.68	4666.56/3963.02	345.00	4321.56	358.54
ZK208	312.81	4738.99	4641.34/4328.47	215.00	4426.34	97.87
ZK250	724.31	4719.71	4719.61/3995.48	265.00	4454.61	459.13
ZK300	803.04	4758.17	4854.34/4041.30	360.00	4494.34	443.04
ZK301	439.36	4715.15	4662.27/4222.90	215.00	4447.24	224.36
ZK350	902.50	4728.05	4734.94/3832.44	200.00	4534.94	702.50
ZK403	789.25	4738.80	4710.65/3921.30	230.001	4480.65	559.35

Table 2 Pressure Gradient of the well

Well No.	Pressure gradient of the well (pa/m)
ZK200	10096.7884
ZK203	10255.6444
ZK206	9889.1598
ZK207	9535.9538
ZK208	11021.5875
ZK250	8595.8800
ZK300	7501.3504
ZK301	9914.7930
ZK350	8857.9564
ZK403	8889.6218

Table 3 Step well test of the 4 wells

Well No.	Flow rate (L/s)	Wellhead pressure (kg/cm^2)	Wellhead temperature (ºC)
Zk403	51.39	6.0	164
	32.78	10.4	180
	20.00	12.6	189
Zk203	54.86	7.3	163
	35.28	8.3	172
	23.89	11.5	185
	/	8.7	134
Zk200	21.67	3.1	127
	18.61	3.5	130
	17.50	3.6	130
	16.67	3.7	135
	0.00	8.6	81
Zk208	100.83	11.9	190
	58.60	12.8	195
	26.94	14.2	200
	0.00	10.0	26

Table 4 Draw down from observation well

Well No.	Well Depth (m)	tance from No.208 (m)	Draw down of water level (m)
ZK208	312.87	0.0	80.30
ZK203	386.00	200.0	14.60
ZK207	703.54	370.0	11.80
ZK30	803.54	715.0	12.61
ZK150	603.88	360.0	0.08
ZK200	606.22	215.0	3.10
ZK250	724.13	510.0	0.00

Table 6 Calibrated parameters of the well

Well No.	Effective Thickness (m)	Permeability (m^2)	Code name of the Sub area
Zk200	140.0	$0.462.10^{-14}$	A
Zk203	16.0	$0.158.10^{-12}$	A
Zk206	150.0	$0.720.10^{-15}$	C
Zk208	40.0	$0.880.10^{-13}$	A
Zk403	95.0	$0.834.10^{-13}$	B
Zk101	76.0	$0.218.10^{-14}$	Outside
Zk302	120.0	$0.124.10^{-16}$	D
Zk402	140.0	$0.161.10^{-15}$	D
Zk502	159.0	$0.868.10^{-14}$	D
Zk300	142.0	$0.242.10^{-14}$	A

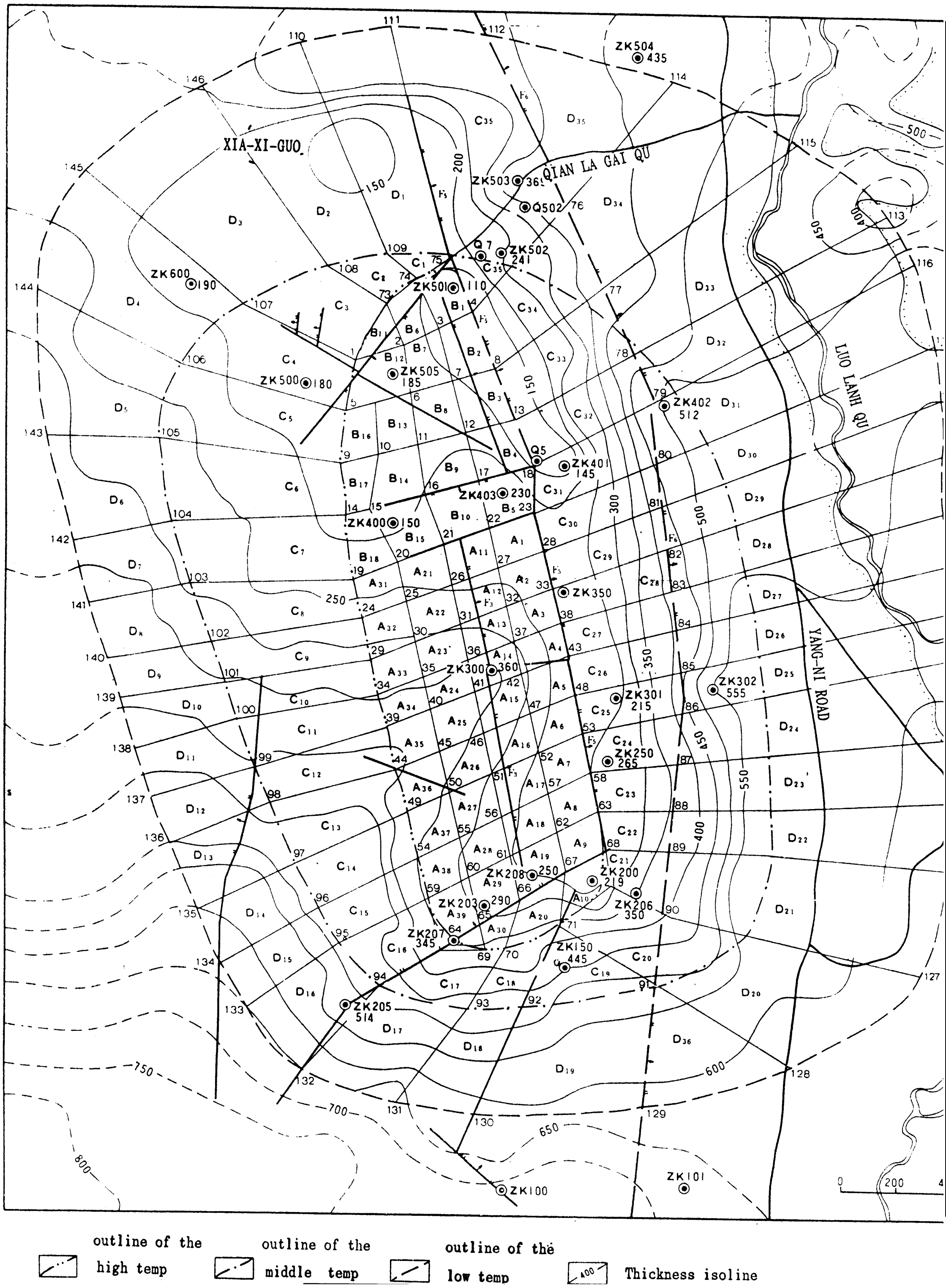
Table 5 Lone Term Well test data (record at shut in well for 1-5min)

Well No.	Well head temperature (ºC)	Temperature of down hole(ºC)	Wellhead pressure (kg/cm^2)	Lip pressure (kg/cm^2)	Diameter of the well pipe (cm)	Total flow rate (t/h)
Zk200	127	172	2.48	0.77	15.7	68.6
Zk203	155	201	4.58	1.58	19.7	178.94
Zk208	171	207	8.18	2.18	19.7	236.51
Zk403	164	190	6.18	2.38	15.7	180.58
total	/	/	/	/	/	665

Table 7 Reservoir Planning Production Scheme

First scheme			Second scheme			Third scheme		
Block No	Well No	Production rate(kg/s)	Block No	Well No	Production rate(kg/s)	Block No	Well No	Production rate(kg/s)
A10	ZK200	20.00				A10	ZK200	22.22
A19	ZK208	67.50	A19	ZK208	33.33	A19	ZK208	33.33
A29	ZK203	51.39	A29	ZK203	33.33	B29	ZK203	33.33
B 5	ZK403	51.39	B 5	ZK403	33.33	A 5	ZK403	33.33
			A 3	ZK303	33.33	A 3	ZK303	33.33
			A 5	ZK304	33.33	B 5	ZK304	33.33
			B 1	ZK506	22.22	B 1	ZK506	22.22
			B 9	ZK450	27.78	B 9	ZK450	27.78
			B15	ZK405	27.78	B10	ZK404	33.33
						B15	ZK405	27.78
Total production		190.28	Total production		244.43	Total production		299.98

Figure 1 Isoline Map of The Thickness For The Cap Rock
In Yang Yi Xiang Geothermal Field



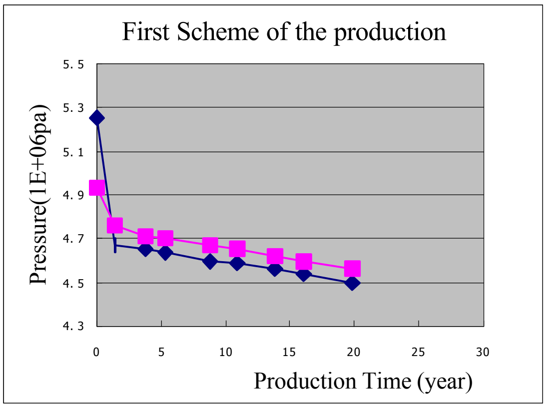


Figure 2 pressure draw down for the first scheme

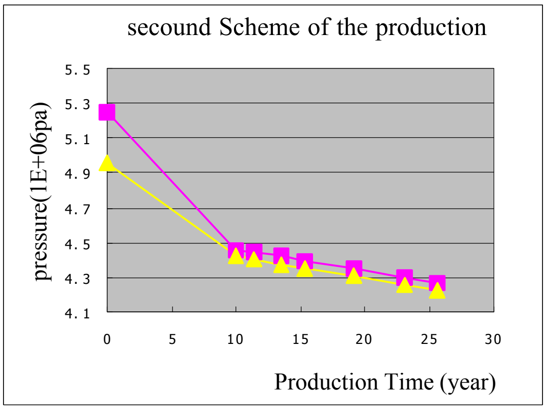


Figure 3 pressure draw down for the second scheme

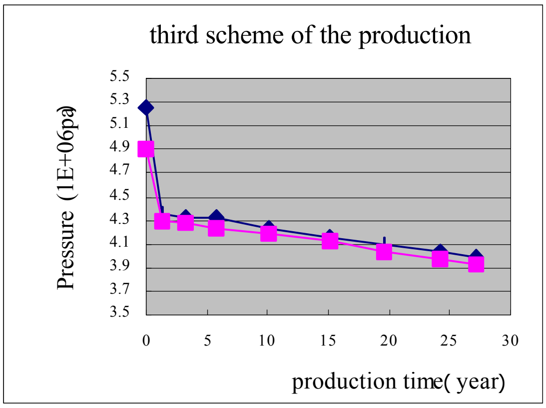


Figure 4 pressure draw down for the third scheme

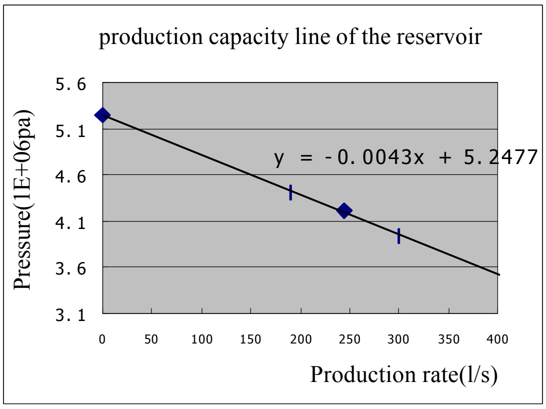


Figure 5 capacity line of the reservoir