PROJECT FOR DEVELOPMENT OF THE MUTNOVSKY GEOTHERMAL FIELD, KAMCHATKA , RUSSIA

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ABSTRACT

This paper presents a brief description of the "Project for development of the Mutnovsky geothermal field for 80 MWe production" (Perveev S.L. and Zorin D.G. (1992)) , which was made under the directive of "Kamchatenergo" . This paper also includes some later additions to this project . The project is to incorporate exploration data into power plant design. So ,the main goals of the project are : (1) optimal exploitation Mutnovsky field design, (2) input data for power plant design.

Key words: Kamchatka, Russia, Mutnovsky geothermal field, Development plan, Resources.

INTRODUCTION

The project for development of the Mutnovsky field is based on the long term flow tests and a huge drilling data. Generally, that is allows more accurate exploitation reserves estimations , that were confirm by Kamchatka geothermal field exploration experience. Mutnovsky is a unique geothermal field in the world because of the volume of drilling per unit area before exploitation , and this is a reason for analysis too.

MUTNOVSKY GEOTHERMAL FIELD, COMMON INFORMATION

The Mutnovsky geothermal field is located close to the northern foothills of the Mutnovsky volcano , it occupies area with 10 km length in north-east direction and 3-4 km width. The Mutnovsky field is on 50 km from the nearest village Termalny. There is a 66 km road with asphaltic cover from Termalny to Petropavlovsk-Kamchatsky, and there is a road with ground cover from Termalny to Mutnovsky field , some parts of wich are avalanche prone .

The landscape is hilly with an average elevation of 1000 m above sea level. There are precious metals deposits, building stones guarries and a number of thermal manifestations around of the Mutnovsky geothermal field.

The winter is long and snowy .The summer is short and rainy , with strong winds and frequent fogs. The average air temperature is -1.4 C (summer +11 C, winter -11 C). Average precipitations is 3500 - 4000 mm, snow thickness is up to 7 m (up to 17 m in canyons). Snow cover lies from October to july.

Exploration work in the Mutnovsky geothermal field began in 1978. Geological, geophysical and geochemical work has been done since that time. Eighty-eight boreholes were drilled total depth 122256 m. Thirty-two wells encountered steam-water mixtures. Interference flow-tests and single flow-tests , tracer tests etc. were made too.

The following two hydrogeological units were identified on the basis of temperature and fluid circulation conditions in the Mutnovsky geothermal field: (1) Upper unit of cold meteoric waters with active circulation at 100-400 m depth occures in quaternary ignimbrites , tuffs and lavas , and (2) Lower unit of two-phase and single-phase high temperature fluids occures in thick sequence of oligocene-pliocene volcanogenic (dominant) and sedimentory rocks.

The lower unit rocks are significantly consolidated and hydrothermally alterated. High permeability related to fractures and crash zones , implies anisotropic properties of a fracture type reservoir. Water levels in wells are low : 500 - 700 m below earth surface. The temperature distribution and water levels distribution analysis confirm existance of two main flow compositions: regional flow in a east direction , and local ascending high temperature fluid flows. A two-phase zone is located in the center of the field , and a single phase high temperature fluids widely distributed beneath . They have different temperatures, pressures and chemical composition, accordingly.

Average temperature of two-phase zone is 245 C, while that of the sinale-phase fluid zone is 250 - 320 C. Enthalpies of the two-phase wells vary from 1000 kJ/kg to 2700 kJ/kg, depending of discharge conditions. Average weight gas content of fluids is 0.14% , gas composition is carbonate or carbonate-nitric , with 6% sulfure hydrogen volumetric content. Single-phase zone fluids have chloridium-natrium composition with 250-300 mg/kg chloridium content and 120 - 820 mg/kg silica acid content , and total mineralisation 1.5 - 2.5 g/kg, pH is about or slightly more 7.0.

EXPLOITATION RESERVES AND READINESS FOR EXPLOITATION

The readiness geothermal fields for exploitation in Russia defines on the basis of exploitation reserves category. Exploitation reserves category estimations is the main result of exploration works , and its needs a special state authority approval.

"C1" category is nesessary for the industrial development of the Mutnovsky geothermal field. Last estimations of the exploitation reserves of the Mutnovsky geothermal field was made in 1991. The sum of real steam rates of all two-phase wells by the end of 4-year interference flow tests plus steam rates of other wells during single flow tests were refer to "C1" category. We use special reducing coefficients for steam rates from single flow tests (reflecting possible interference and drowdown), these coefficients estimations were based on complex studies. "C1" exploitation reserves estimated were 156.2 kg/c for 30 years exploitation period.

"C2" is less reliable category. Estimations were made on the basis of Darcy formulae for ascending flow, with permeability coefficient, horisontal section area of ascending flow , and vertical pressure gradient gradient as an input data. "C1" plus "C2" exploitation reserves gives 332.2 kg/s of steam for 30 year exploitation .

"P1" category is less reliable than "C2" was estimated on the basis of heat storage in the reservoir and extraction coefficient. It adds 147 kg/s to the previous two categories , e.g. "C1" and "C2".

Power plant modules 20 MWe with steam consumption 39 kg/s each will be installed during exploitation. It is possible to install 4 x 20 MWe modules , or 80 MWe total (4 x 39 kg/s = 156 kg/s).

We think also ,that the total power plant capacity will probably increase up to **160** MWe (8 x 20 MWe modules , or 8 x 39 kg/s = 312 kg/s of steam) . But the final desigion will take during exploitation of first 80 MWe power plant , after exploitation reserves revaluation.

There are 13 productive wells (Fig.1) that is possible to use as exploitation wells today. We also have 5 additional wells , that is technically suitable for production , but was not tested. There are 4 reinjection wells at a North reinjection site and 3 reinjection wells in a North-East reinjection site . There are 5 sites suitable for power plant modules installation in the Mutnovsky geothermal field .

EXPLOITATION **OF** THE FIELD

The project consideres two stages of exploitation of the Mutnovsky geothermal field, 1st stage and 2nd stage correspondingly. Two-phase mixture will be transported from wells to power plant. Steam will be delivered to the power plant with 0.7 MPa pressure. It means that the wellhead pressure has to be 1.0 MPa in wells , supplying steam for site #3 power plant modules, and 0.8 MPa in others wells. We based on existing wells production characteristics (Table 1) and power plant increase possibilities .

Table 1. Production wells rates.

Well #	Production rates, kg/s	Well #	Production rates, kg/s
029W	43	01	38
016	21	26	24
24	15		
013	35	055	30
014	8	049	30
037	30	045	35
048	65	022	25

The following scheme of the 20 MWe power plant modules installation is designed: site #2 - two modules 2 X 20 MWe, site #3 - two modules 2 x 20 MWe. The first modules will be installed in the site #2.

Wells 014 , 016 , 26 , 24 , 029W will supply 65.8 kg/s of steam to the site #2. Well is 4 suggested to be used too. Additional two wells is planning to drill here : the first to penetrate single-phase zone , the second to penetrate two-phase zone.

Wells 048 , 049 , 055, and 037 will supply 46.0 kg/s of steam to the site #3. Wells 047 , 053 , and 017 are suggested to be used too. Additional drilling of the three wells is needed here, but the number of additional wells may be revised after wells 047 , 053 , and 017 flow tests.

Special attention will be alloted to the thermohydrodynamic regime during the first stage of exploitation , because its important for exploitation reserves revaluation. Permanent well head pressure and steam rate measurement will be conducted on exploitation wells, enthalpy and total rate of each exploitation wells will be check periodically too, pressure decline in monitoring wells will be registered, etc.

Preliminary shedule for 2-nd stage power plant modules installation is the following: site #1 - one 20 MWe module, site #2 - 3 x 20 MWe modules, site #3 - 2 x 20 MWe modules, site #3' - one **20** MWe module ,and site #4 - one 20 MWe module. Wells 01, 013 , 022 , 045, and untested well 10 will be involved in this project. 18 additional exploitation wells and 4 additional reinjection wells are suggested to drilled to deliver additional steam for 2-nd stage of the project. Note, that the volume of additional drilling may be decrease due to the two-phase fluid redistribution system between power plant sites.

CONCLUSIONS

Sufficient steam reserves to generate 80 MWe had been demonstrated on the basis of interference and single flow tests in the Mutnovsky geothermal field. Preliminary estimations confirm the possibility of the power plant extention up to 160 MWe capacity. Reinjection program design was based on cooldown estimations and its satisfies to co-generation power plant needs.

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REFERENCES

Perveev S.L. and Zorin D.G. (1992) Project for development of the Mutnovsky geothermal field for 80 MWe production. Kamchatka Hydrogeological Expedition, Thermalny, 80 pp.

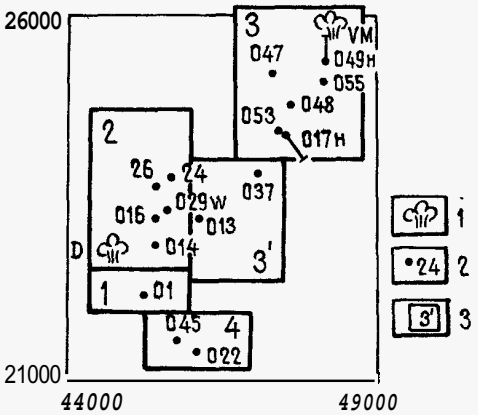

Figure **1**. Location of the natural discharge areas (1) (D -Dachny, VM - Verkhne-Mutnovsky) ,exploitation wells (2) and modules sites **(3)** in the Mutnovsky geothermal field.