RECENT GEOTHERMAL ACTIVITY IN JAPAN

J. SUYAMA

Japan Petroleum Exploration Co., Ltd.

ABSTRACT

The recent tentative assessment of the Geological Survey of Japan indicates a production potential for electricity from high-temperature hydrothermal convection systems of more than 21,500 MWe for 30 years. However, by 1986, the total installed capacity of the operating geothermal power plants is only 214.6 MWe.

In this paper, together with the presentation of the Japanese activity of exploration and development of geothermal energy, brief review of nation's research effort is made with the special reference to the following geoscientific study:

- study on the nationwide resource assessment
- in-depth study on the prominent geothermal fields

looking for deeply seated resource

1. INTRODUCTION

Energy requirements in Japan are constantly increasing with the economic growth and the advance of living standards of the people. More than fifty five percent of her energy requirement is met by crude oil which almost entirely come from abroad. At the long term energy policy, the high degree of dependence on crude oil for the energy supply must be reduced, and the development of alternative energy sources as well as energy saving should be promoted. Japan is situated within the Circum Pacific Volcanic Belt and has about one hundred seventy Quaternary volcanoes, among which sixty seven are active. A lot of active geothermal fields have been found within volcanic zones. Geothermal resources are expected to be an abundant energy source in Japan available with current technology and is also expected to increase the potential of available energy with the further exploration and assessment and with further research and development of utilization technology.

2. ROLE OF GEOTHERMAL ENERGY AS ONE OF THE DIVERSIFIED ENERGY SOURCE

It is supremely important problem to secure steadily dependable energy supply source. Development of alternative energy and the diversification of the energy source should be systematically promoted. Geothermal energy is one of the attractive domestic energy resources and is expected to be enhanced by an understanding of the nature, distribution and magnitude of the Nation's geothermal resources. Assessment of the magnitude and distribution of the Nation's geothermal resources is essential to make a plan of long term energy supply policy.

In Japan, the first quantitative assessment of high temperature (>150°C) hydrothermal convection system in nationwide scale was made by Geological Survey of Japan (Ohyama, Y. et al., 1984). In this assessment, data obtained in the nationwide geothermal resources survey and other geological, geophysical and geochemical information acquired by Geological Survey of Japan were exclusively used. The assessment was carried out for fifteen blocks (Fig. 1) by use of essentially the same methodology applied to the assessment of hydrothermal convection systems with reservoir temperatures more than 150°C in USGS, Circular 790. (Brook, C. A. et al., 1979).

As a proper treatment of this assessment, (a) gravity basement data were used to determine the depth to the bottom of the geothermal reservoir, and (b) Curie isothermal depth was used to determine the underground temperature distribution (Oka, Y. et al., 1985 a) assuming linear geothermal gradient, constant surface temperature (5°C) and Curie temperature of 500°C. Curie temperature of 500°C may be reasonably adapted from the comparison with existing well temperature data (Oka, Y. et al., 1985 b). The upper limit of reservoir is taken at 150°C isothermal surface obtained from above-mentioned temperature distribution.
For the assessment work, the volume method is chosen assuming the rock volumetric-specific heat to be 2.15/°C and the reservoir porosity to be 15%, so volumetric specific heat of rock plus water to be 2.73/°C within the geothermal reservoir. The reference temperature is the mean annual temperature and for simplicity is assumed to be constant 15°C for the entire territory.

Data in calculation are used the 500m grid-data value volumetric specific heat of rock plus water to be assuming the rock volumetric specific heat to be on depth of top and bottom of reservoir and vertical water system which is greater than 150°C. This exclusively limited to the area of 15 blocks, in which value (Table 1) shows a theoretical maximal value. The calculation is also made assuming that the reinjection is totally there. So, for these reason, the current assessment calculation does not show a theoretical maximal value. For these reason, the current assessment work is tentative, this is a first nation's geothermal resources assessment which has been done by using systematically acquired data.

2.1 Geothermal energy utilization update of Japan

3.1 Geothermal power plants in Japan

At present, nine geothermal power plants with a total generating capacity of 214.6 MWe are in commercial operation, as shown in Table 5. The annual electric power production from these geothermal power plants reaches totally 1.115 TWh in 1987. Among them, geothermal power plants of electric utilities are five plants, whose total capacity is 198 MWe, and whose total annual power production was 1.115 TWh in 1987. The share of this geothermal power production is only 0.5 percent of total power production by electric utilities in 1987. However, the share of geothermal power production is expected to increase to 0.8 percent (power production 6 TWh) in 1995 and to 1.7 percent (power production 15 TWh) in 2000.
The objective of this program is to develop the binary blows out in abundance with vapor. Two types of LMW using intermediate temperature geothermal water. The main objective of this program is to develop the geothermally promising but are still risky for exploitation technologies. The Agency of Natural Resources and Energy has conducted the pioneering of geothermal resources survey, named, Survey to identify and promote geothermal energy technologies is concentrated on following three item. Development by granting of subsidies for drilling cost and the basic data on the geothermal resources of all over Japan is estimated 82.9 MWt. Nation's geothermal resources assessments have been carried out since 1973. Until now, Nation's geothermal resources assessments have been carried out since 1973. In 1980, the New Energy and Industrial Technology Development Organization (NEDO) has participated in the joint international research and development program to promote the Phase 2 Hot Dry Rock project at Fenton Hill in the United States of America from Oct. 1983 to Sept. 1986. From 1984, NEDO has "also undertaken the nation's program on development of component technology for hot dry rock project in order to demonstrate the economic feasibility of such system. The test field is selected in the Hijiori geothermal field, Fukuoka prefecture. The idea of geothermal exploration with high temperature hot dry rock was established as the national body for promotion of the project. NEDO also conducts the pioneering structural drilling for sites selection. (a) Basic research and development of deep geothermal resources assessment. (b) Comprehensive multidisciplinary studies of major geothermal areas aiming at exploration and assessment of deep geothermal resources. (c) Research on exploration and assessment technology of deep geothermal resources. The extensive geothermal activity is indicated by the existence of numerous hot springs and fumeroles, and most of them are located within the Quaternary volcanic areas. The hundred eleven sites of steam fumeroles, boiling point springs and hot springs having a temperature exceeding 150°C, were identified from the documentation study. The area having such high temperature hot dry rock was considered to be promising for geothermal power production. Geothermal Survey of Japan conducted the three years reconnaissance survey over thirty area selected from above-mentioned one hundred eleven sites data since 1973. Agency of Natural Resources and Energy has also conducted the structural drilling for sites selected from the result of this reconnaissance survey. Two hundred of promising geothermal fields were selected. (b. Jun., 1987). After the completion of this reconnaissance survey, two hundreds of promising geothermal field were selected. Until now, Nation's geothermal resources assessments have been carried out since 1973. In these assessment, several different approaches were included as the economic evaluation method, the heat budget method, the stored volume of geothermal fluid, etc. However, these estimates are empirical and are derived from the insufficient data under the inaccurate assumption.

2) Nationwide geothermal resources survey to acquire the basic data on the geothermal resources over the Japanese islands was conducted by NEDO with the cooperation of Geological Survey of Japan from 1980 to
The objective of this survey is to delineate the geothermally promising areas by use of airborne geophysical, satellite remote sensing and gravimetric methods (K. Ogawa, 1985). Geological Survey of Japan, which took charge of the analysis and integration of the results of these surveys, started to develop the geothermal information database system SIGMA (System for Interactive Geothermal Mapping and Assessment) since 1980, in order to make the nationwide and regional geothermal resources assessment map by use of the data of the nationwide geothermal resources survey, other geological, geophysical and geochemical information acquired by Geological Survey of Japan and the government owned geographical information. (K. Hamada et al., 1986, Y. Tsu et al., 1987).

Therefore, SIGMA has been designed to accept various application program for a standard retrieving and displaying (menu system), data manipulation and atlas production. The final goal of this research program is to publish a geothermal potentiality assessment map of Japan by using the geothermal data base system SIGMA.

For the purpose of the investigation on the possibility of the utilization of the deeply seated high temperature geothermal resources, the survey project of large-scale deep geothermal resource was originally planned as a part of the Sunshine Project and promoted as a national project under the financial support of the Agency of Natural Resources and Energy from 1978 to 1986. This project (MITI, 1987) implies unconventional and inexperienced items in respect to the assessment of deep geothermal resources and its exploration. MITI requested the Geological Survey to provide full assistance (Hase, H. et al., 1985). The Hohi geothermal area, which is located in the Hoku volcanic region on the border between Oita-Kumamoto Prefectures, is one of the most prominent active geothermal areas and was selected as the survey area of this project.

Research work on the appraisal of the geothermal system in the Hohi geothermal area was initiated by Geological Survey of Japan since 1980. In this project, surface geological survey, gravity survey and aeromagnetic survey were conducted over a wide region from Beppu, Huku volcanic to Kikai volcano to clarify the regional structural setting. The target area for the drilling survey in the Hohi geothermal project is about 200 km centered at Mt. Waite (elevation: 1,500 m). Various survey items expected to be useful for geothermal exploration were applied in and around this area. The drilling survey includes seven "intermediate" depth drilling ranging from 1,100 m to 1,400 m depth SW series structural drilling), and five deep drilling ranging 2,100 m to 3,100 m depth SW series drilling for test well.

The multidisciplinary research work on the appraisal of this geothermal area was attempted through modeling of the geothermal system using the geothermal data base system SIGMA of the Geological Survey, in which whole geological, geophysical and geochemical data obtained for the Hohi geothermal survey were filed and processed. In this project, prior to start of the survey, numerous geothermal models both in Japan and abroad were studied to make the most reasonable initial working model for deeply seated geothermal resources. In the initial working model, the structural setting of...
the most promising deeply seated geothermal resources is considered to be that located in and around the large domal structure formed by intrusion of high temperature rock body originated from reactivated magma in the caldera of extinct large volcanoes.

Considering the technological problem, national R & D program has started since 1974 and promoted continuously. In terms of the problem on resource exploration and assessment, intensive research works have been done in Geological Survey of Japan with the cooperation of NEDO. The DY-1 (2,618 m depth) showed the convective type temperature distribution with maximum temperature 292.7°C at 703 m depth. From the results of this drilling survey and magnetotelluric survey, it can be considered that, Kyu uplift belt is not due to the reactivated magma of young volcanic rocks (Kuju volcanic rocks) and is older than that of the initial working model. Based on such idea that the heat source associated with the Kyu volcanic activity is distributed not only in the Kuju uplift belt but also extended towards the Shishimuta subsidence belt, corresponding to gravity low, which is located in northeastern side of the Kyu uplift belt, the initial working model was revised. This means that deeply seated geothermal reservoir would be possibly distributed within the Shishimuta subsidence belt and the transition zone between Kyu uplift belt and Shishimuta subsidence belt, i.e. Jizobaru area (Fig. 2). Results of the additional magnetotelluric survey and study on geophysical and geochemical data obtained from the surface and the wells in these areas, better seismic and geothermal area (50 km × 68 km) is also one of the prominent active geothermal area. Geothermal power plants, Makuzuka (22 MWe), Osuna (9.5 MWe) and Kaho (50 MWe) are in operation and Sunioka and other power station are planned in this area. Eruptions geothermal area (57 km × 68 km) is also one of the prominent active geothermal area, where Onikobe power plant (325 MWe) is in operation and other geothermal field are under development.

Geological Survey of Japan has been active in the development of methods for geothermal exploration. Development of electric and electromagnetic techniques to determine the geometry of geothermal system and of underlying magma bodies, bodies are performed. Research on radiometric dating of igneous rock, geosynthetic study of volcanic rock and thermal historical study of geothermal systems by hydrothermal rock alteration are also carried out.

6. CONCLUSION

Delay of commercial geothermal development is mainly due to technological and institutional uncertainties. Concerning with the technological problem, national R & D program has started since 1974 and promoted continuously. In terms of the problem on resource exploration and assessment, intensive research works have been done in Geological Survey of Japan with the cooperation of other governmental and non-governmental organizations. To develop the exploration system for regional and deep geothermal resources, in-depth multidisciplinary studies have been carried out in three prominent geothermal areas, i.e., Hobi, Sengan and Kurikoma areas.

From the integrated data analysis on geological, geophysical and geochemical data obtained from the surface and the wells in these areas, better understanding and modeling of hydrothermal system have made good progress.

These R & D works and the financial support from the government are a great help to reduce the exploration risk. The requirement for commercial exploitation of geothermal field are legal barrier and institutional uncertainty. In Japan, the national identified potential geothermal field are found in national park and are subject to the restrictions of the Environment Agency. The criteria for geothermal development within national park required permission by the Director General of the Environment Agency. After giving permission, the Governor must take the matter to the Hot Spring Council whose members are mainly local bath owners. Under the circumstances, the Governor's permission would not to be easily obtained because the definition of geothermal resources and the onshore ownership right have not yet been made clear, deeply seated hydrothermal reservoir has been identified at the depth of 2.5 km and over.

Geological Survey of Japan has been conducting similar kind of surveys. The Geological Survey of Japan with the cooperation of the Director General of the Environment Agency, the Hot Spring Council and Ministry of Environment, have made good progress.
SUYAMA


