Proceedings World Geothermal Congress 2005
Antalya, Turkey, 24-29 April 2005

# The New National Standard for Geological Exploration of Geothermal Resources in China

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**Keywords:** geothermal, geological exploration, national standard, China

## ABSTRACT

The first national standard for geothermal geological exploration was stipulated in 1990, and it had played an active role in ensuring the quality of geothermal exploration projects in the country since then. With the rapid growth of the market economy, the fast growth of geothermal utilization and the improvement of geothermal exploration techniques in recent years, it has been necessary to put forward a new standard related to geothermal exploration in the country. A working group composed of six experienced geothermal professionals of different specialty was set up in 2001 to revise the old standard. The work was completed at the end of 2002, and will be put into application soon. The changes in the new standard mainly focused on the classification of geothermal resources, the economical feasibility of geothermal development, the phases definition of geothermal exploration, geophysical and geochemical exploration, reinjection of waste geothermal fluid, modeling of geothermal systems, especially numerical modeling for geothermal systems with a production history that is more than five years and the updating of models on a regular basis.

## 1. INTRODUCTION

The first national standard for geothermal geological exploration in China was stipulated in 1990 (Yang et al.). Since then, it has played a very important role in the standardization of geothermal exploration and development in the country. With the gradual establishment of the market economy system, geothermal development was also changed from state-investment to company-investment. Therefore, that standard of the former Soviet Union has no longer been suitable to the present situation of the country. On the other hand, geothermal utilization in China increased very fast and more and more new techniques were applied recently in the geothermal exploration. This also asks for a new standard. Further more, the sustainable development of geothermal resources, which has been widely accepted by the government and the geothermal community in the country recently, is another reason for revising the standard.

In 2001, the Geothermal Committee of China Mining Association, entrusted by the Ministry of Land and Resources, started the revision of the national standard for geothermal geological exploration. The working group is composed of 6 scientists including the authors. Based on the suggestions from different cities, provinces and autonomous regions, the standard was completed in October 2002 and approved by the National Geological Standard Committee after then. The standard includes the classification of geothermal resources, the definition of the phases of geothermal geological exploration and geological work that should be carried out in different phases, especially the requirement of geophysical and geochemical explorations, the requirement and methods of geothermal resources assessment as well as reinjection. (Bin et al., 2002) The contents and most important features of the standard will be introduced in the paper.

## 2. THE NEEDS OF A NEW STANDARD

The first national standard for geothermal geological exploration in China was stipulated in 1990 based on the geothermal exploration practice in the country. As with most of the geological exploration standards in that time, it followed the mode of the former Soviet Union, designed for the planned economy of the Socialism System. In that time, the investment of most geological work was by the government, and the purpose of the geological exploration concentrated on making clear the reserves of mineral resources on the working areas. For geothermal exploration, exploration wells were often drilled for geological purposes, and production wells were often the by-products of the exploration. With the gradual changing from planned economy to market economy, more and more investors of geothermal development in the country have become enterprises, and a lot of them are private companies. They drill geothermal wells for production rather then geological purpose.

The technical development in geothermal exploration in China has been tremendous since 1990, accompanying the rapid advancing of geothermal development. Firstly, the depth of wells has greatly increased since 1990: In the time of making the old standard, the depth of geothermal wells was mostly less than 1500m, but it may be more than 4000m recently. In the same time, the drilling and well completion technique used for geothermal wells was also improved greatly. Secondly, the geophysical methods used in geothermal exploration changed a lot in China, because of (1) the needs of understanding the geological conditions in a greater depth; (2) the situation that geothermal development is often in cities or highly industrialized areas and some traditional geophysical exploration methods are no longer suitable for in this kind of areas; (3) some new technique has been used to overcome the problems of those traditional methods. Thirdly, reinjection has been carried out in a few geothermal fields in China and it is believed that more and more reinjection will be applied in the reservoir management in the country. Lastly, the reservoir

modeling technique in geothermal study has developed a lot since 1990: before the old standard was put into effect, only very simple reservoir models could be setup in China, but recently, some complicated numerical models have been setup or are being setup for a few geothermal fields in China. Therefore a new standard is needed to include all these technical development in geothermal exploration.

Sustainability has become the main theme of social development presently (Rybach, 2003; Stefansson and Axelsson, 2003). As a kind of natural resources, geothermal utilization should also abide to the principle of sustainable development. On the other hand, with the increase of geothermal production, rapid decline of reservoir pressure has been found in some geothermal fields in China, such as those in Tianjin and Xi'an (Wang and Li, 2002; Xue and Wang, 2002). This means that it has been highly necessary to include the geological work for geothermal fields under production in the new standard, so as to better the management of geothermal resources in the country.

## 3. THE CONTENTS OF THE NEW STANDARD

In the new standard, its scope of application is defined as the geothermal geological exploration activities concerning the planning, reserve approving, resources / reserve reporting to the government, as well as related transfer of geothermal mining permit, financing and investment of geothermal projects. The new standard will only regulate the geothermal geological exploration for liquid-dominated resources, not including HDR, considering that there is still not any HDR project in China. The main contents of the standard are as follows:

(1) The phases of geothermal geological exploration are defined as reconnaissance survey, pre-feasibility study, feasibility study and production period, and the geothermal resources/reserve is defined accordingly (considering economical factors in the same time).

(2) The various data that should be obtained from geological exploration are defined. And works should be done, the amount of works, the positioning and the quality requirements of the works in different phases are defined in the standard, taking into account of the type and scale of the geothermal field. These works include data collection, remote sensing, geological survey, geochemistry survey, geophysical survey, drilling of geothermal wells, well tests and reinjection test, lab analysis of geothermal fluid and rock, as well as monitoring of geothermal systems.

(3) Geothermal resources or reserve calculation and assessment is taken as one of the most important parts, and the principles, parameter requirements, methods of resources / reserve calculation are described.

(4) The requirements, related criterion and methods for assessing the quality of geothermal fluid for various utilizations are also defined in the standard.

(5) The assessment of environmental impact of geothermal development projects is also defined as an important aspect in the geothermal geological exploration.

(6) The standard contains a number of annexes including standard terms of geothermal (with English translation), calculation methods of geothermometer, geothermal fluid sampling and preserving, methods of geothermal resources / reserve calculation and assessment, nomenclature and unit system for parameters often used in geothermal exploration and research and so on.

## 4. A FEW KEY POINTS OF THE NEW STANDARD

### 4.1 Phases Definition of Geological Exploration

About 15 years ago, almost all the investment for geological explorations was from the government in China. But presently, more and more geological exploration that is for certain construction projects is funded by enterprises. In the geothermal sector, almost all the investments are from the market. This asks for changing the phase definition of geothermal geological explorations. On the other hand, there are often a lot of geothermal wells belonging to different investors in the same geothermal area. This asks for over-all management of the resources in the same areas.

In the standard, large geothermal projects are divided into four phases: reconnaissance survey, pre-feasibility study, feasibility study and production period. And for small-scale projects, these phases can be simplified.

In the phase of reconnaissance survey, geological exploration is mostly concentrated on data collection (including regional geology, geophysical, geothermal etc.) and field survey of geothermal manifestations, and very few wells may be drilled in this phase.

Pre-feasibility study includes surface geological survey, geophysical and geochemical survey, as well as necessary drilling and testing, aiming to find out the proper areas for geothermal development, define the distribution and characteristics of the geothermal reservoirs, find out the temperature and chemical composition of geothermal fluid, estimate geothermal resources, assess the potential of geothermal development of the target area, and put forward pre-feasibility study reports.

Feasibility study involves detailed geological, geophysical and geochemical survey, drilling of wells for geological and production purposes, well testing and monitoring of the geothermal systems, on the basis of reconnaissance survey and pre-feasibility study. The aim of feasibility study is to (1) make clear the distribution and characteristics of the geothermal reservoir; (2) boundary conditions and temperature field of the geothermal system; (3) the temperature, pressure and chemical composition of geothermal fluid; (4) the production capacity of geothermal wells; (5) the fluctuation of reservoir pressure and change of chemical composition of geothermal fluid; (6) calculate and assess the allowable production capacity of the geothermal field on a sustainable production manor; (7) put forward feasibility study reports.

In the previous standard, the geological works in geothermal fields under production was not included. Recently, the idea of sustainable development has been received in a very wide extent, and the rational management of geothermal resources has been taken as one of the most important aspects of geothermal development. In the new standard, the geological works for geothermal field under production are clearly defined, including monitoring, reinjection, modeling of the geothermal system and drilling of new wells etc. It is also stipulated that the reservoir model for a geothermal field under production should be updated at least every five years.

### 4.2 Economical Rationality of Geothermal Development

Whether geothermal development is economically rational, it depends on not only the features of the geothermal resources, but also the technical and social development in the geothermal area. But in most cases, the buried depth of the geothermal reservoir is the most important factor in

assessing the economical rationality of geothermal development. In the standard, if the reservoir depth is less than 2500m, the geothermal development from the reservoir is taken as economical; otherwise, it is taken as not economical. On the other hand, if the specific capacity of most geothermal well in a geothermal field is less than 5m3/d.m, the geothermal development in the geothermal field is taken as not economical.

### 4.3 Classification of Geothermal Resources/ Reserve

In the standard, it is stated that geothermal resources are all the heat stored in the geothermal reservoir, including both identified and unidentified. According to the degree (phase) of geological exploration undertaken in the study area, geothermal resources can be classified as identified and unidentified or forecasted; On the other hand, they can be divided into economical and uneconomical according to the depth of geothermal reservoir, temperature and chemical feature of the geothermal fluid and the specific capacity of geothermal wells.

Identified geothermal resources can be further classified as prospected, controlled and inferred, which are the output of geological exploration in production period, feasibility study, pre-feasibility study respectively; and unidentified or forecasted geothermal resources are the output of reconnaissance survey. The prospected geothermal resources / reserve are based on the monitoring data and other reservoir engineering studies for more than 5 years of production.

### 4.4 Geophysical and Geochemical Exploration

In China, especially in big cities such as Beijing and Tianjin, The geothermal needs have been ever increasing in the past 30 years, and more and more wells were drilled in areas outside the geothermal anomaly. This makes the geothermal development more risky and better geophysical and geochemical exploration methods are needed in sitting new geothermal wells. Fortunately, in addition to the traditional methods of geophysical and geochemical exploration, a few kinds of new methods (such as CSAMT, DPEM and radon gas measurement) have been used in the geothermal exploration in the country, and were found rather useful. In the new standard, the proper geophysical and geochemical exploration methods that should be used in the different phases are recommended.

### 4.5 Reservoir Modeling

In the old standard, the modeling of geothermal systems was not included, because that only very simple modeling could be done for geothermal fields, and detailed numerical modeling was still not used in China in that time. Recently, reservoir modeling has become a key ingredient for geothermal management, is being used in some of the geothermal fields in the country. The data needs for reservoir modeling, the quality control for the process of getting these data, the different methods of modeling (analytical, statistical, numerical etc.) and their use in different exploration phases are listed in detail in the standard.

### 4.6 Reinjection

Reinjection has been taken as an kind of routine work in a large number of geothermal fields in the world (Liu, 2003). In China, reinjection has been started in Tianjin and Beijing, and showed positive effects in counteracting the decline of reservoir pressure and improving the heat mining in a few important geothermal fields in the cities. It is believed that more and more reinjection projects will be carried out in China. In the standard, the guideline of reinjection is defined, and the needs of a proper monitoring system and tracer tests is stressed.

### 4.7 Environmental Impact Assessment

The standard takes the environmental impact assessment of geothermal as one of its important aspects, concerning the discharge of waste geothermal fluid that includes gases (such as $CO_2$, $H_2S$ and other non-condensible gases) and water. It is also stated that the potential land subsidence should be studied and monitored for geothermal reservoirs that are composed of unconsolidated sediment and other compressible strata, and the possible surface caving caused by production from karst reservoirs. The standard also stated that the possible disappearance of geothermal surface manifestations, seawater intrusion in coastal areas, impact to animal and plant resources, and the pollution to aquifers used for cold water supply caused by geothermal development should be taken into account

## 5. CONCLUSION REMARKS

A new national standard for geothermal geological exploration was completed in 2002, to overcome the problems of the old standard that was stipulated in 1990, and meet the needs of geothermal development in the near future in China. It will be put into application soon. It is set up based on the present and future trends in geothermal exploration and development. Although there may be problems in the standard, it will certainly play a positive role in promoting the geothermal utilization and avoiding problems caused by improper application of geology.

## ACKNOWLEDGEMENTS

The authors would like to address their thanks to the Ministry of Land and Resources of China for entrusting them the important work of revising the national standard of geothermal geological exploration. Sincere thanks are also due to all the geothermal professionals and experts that gave their precious opinions and comments on the draft of the standard.

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