BMain Problems in Development and Utilization of Oil Shale and Status of the In-situ Conversion Process Technology in China

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Abstract

The oil shale resources are rich in China - the total shale oil resource is estimated at 47.6×10^9 tons and the recoverable resource is 12.0×10^9 tons. It will have great potential and the advantage to replace conventional energy, but it is not well utilized now. The factors limiting the large-scale development and utilization of the oil shale were analyzed by combining the current development and utilization status of oil shale. Noting the deep burial of many oil shale formations, and considering environmental protection and continuous economic development, the in situ conversion process technology is expected to be the main development technology for oil shale in the future. In studying the development of in-situ conversion process in detail, the characteristics of all kinds of technology were compared and analyzed. The paper puts forward some new research concepts on in-situ conversion process technology for China.

Introduction

For several years, with the sustained and high-speed development of the Chinese national economy, the domestic supply of petroleum has not been adequate, given the oil and gas resources and production capacity in China. The Demand-Supply Gap will become larger and larger (Table 1). Importation is increasing quickly; the dependency on foreign petroleum is becoming larger and larger. Therefore the safety of petroleum supply has been paid more and more attention. Among those methods of ensuring the supply of liquid fuel, shale oil is a realistic energy substitute for petroleum. Efficiently developing oil shale has important significance in China (Bunger, et al., 2004).

Principal problems of oil shale resource development and utilization

The first national evaluation of the oil shale resource, which was conducted between 2004 and 2006, has been completed. The evaluation result indicates that the oil shale resources are rich in China: the total oil shale and shale oil resources are estimated at 719.937×10^9 tons and 47.644×10^9 tons, respectively. This places China as second only to the United States in the world. The oil shale resources are rich and the distribution is relatively centralized in China, so oil shale shows good potential and advantageous conditions as a substitute energy resource.

At present, oil shale resources are used in two ways: one is for power generation and

Table 1. The statistical table of oil production and demand in recent years in china

Year	***Annual Output (billion tons)***	***Demand (billion tons)***
2002	1.67	2.41
2003	1.69	2.53
2004	1.75	2.92
2005	1.82	3.18
2006	1.84	3.29
2007	1.87	3.46
2010	1.92	3.6~3.8

The value for 2010 is projected

the other is as raw material for oil refining.

Principal problems of the oil shale resource for power generation

From the aspect of energy use, oil shale-fired power generation has higher commercial value. But there are four main problems regarding burning oil shale in Pulverized Coal Fired Boilers that have not been resolved.

- Metal corrosion of the Radiant Heating Surface in the firebox is very serious and the firebox is short lived;
- High temperature convective heating surface is too large to effectively perform heat transfer - ash clogging is very serious;
- Explosions often ocurr in Pulverized coal systems; They are very unsafe;
- When the calorific value of oil shale lower than 8,374kJ/kg, the system requires fuel injection to support combustion, making the system uneconomic.

Power generation by fluidized bed combustion technology also has many shortcomings, such as low combustion intensity, large space needs, large bed area, structural complexity, difficulty of control, low heat efficiency and pollution of the environment. Therefore, burning oil shale to generate electricity has not actually achieved development (Yan and Jiang, 2000).

Principal problems of the oil shale resource for extraction of shale oil

In recent times, the demand for petroleum has increased constantly with the steady expansion of the international economy. As a consequence interest in production of shale oil from oil shale has swept all over the world.

The main method for producing shale oil is surface (or underground) mining, crushing and retorting. These techniques have been used for more than 200 years. The method is simple and uses mature technology, but it has many limits and problems. Oil shale under cities and important buildings can not be mined; the destruction of the ecological environment can also be very serious and may not be able to be avoided. These concerns appear in the following aspects:

- *Serious damage of ecological and water quality*: both surface mining and underground mining need to lower the groundwater level below that of the kerogen-bearing rock layer. Mining $1m^3$ oil shale requires using ~$25m^3$ of groundwater. Before releasing underground water into rivers, the solid particles must be settled, so mining water greatly increases the sulfate content of surface water and groundwater. In Brazil, long-term exploitation of oil shale has disrupted the ecological balance as well as the water level and water quality stability of the area near mines.
- Ash pollution is inevitable when oil shale is used to extract the shale oil or directly combusted. Typically, this process will generate a lot of ash. If we do not recover and reuse it, the ash the ash can cover large land areas, will not only cause particulate air pollution, but also may permit metals and trace elements to infiltrate into underground water. Serious pollution can damage the environment and endanger human life and productivity.
- Surface mining covers more land, and the land can not be fully restored (Li et al., 2006; He and Song, 2005).
- China's high-quality oil shale is mainly concentrated in deep zones. Because of the high costs of mining, development of oil shale produces no economic benefits when developed by traditional processes

In-situ conversion process

In-situ retorting entails heating oil shale in place, extracting the liquid from the ground, and transporting it to an upgrading facility. Various approaches to in-situ retorting were investigated during the 1970s and 1980s. The mainstream methods involved burning a portion of the oil shale underground to produce the heat needed for retorting the remaining oil shale. Much of this prior work was not successful, encountering serious problems in maintaining and controlling the underground combustion process and avoiding subsurface pollution.

In-situ conversion processes involve heating the underground oil shale rock directly, cracking it in the ground to generate oil and gas, and producing oil and gas from producer wells. The process is:

- more favourable for development of deep oil shale;
- high in recovery efficiency and low in cost;
- less disruptive of land and less polluting.

At present, more than 10 in situ conversion processes have been developed. The range of technology options can be divided by heating methods (as shown in Table 2) into:

- electric heating processes,
- fluid heating processes and
- radiation heating processes.

Analysis of technical features of in-situ conversion processes by different heating methods has identified the following features of the main heating process options. Electric heating technology (as shown in figure 1) is characterized by technological maturity, ease of control, but slow heating rate. It appears likely that the greater heat loss, high cost, and low oil pressure will lead to lower oil and gas recovery. Fluid heating technology (Figure 2) is characterized by high heat efficiency and by excess pore-fluid pressures. Fractures will gener-

Table 2.Properties of different types of in-situ conversion process technology

Heating Process	Technology	Advantages	Disadvantages	Test
Electric heating process	Shell's ICP Technology	Uniform heating Low heating temperature Protects groundwater Can develop deep, low oil content oil shale	Complex, multi-fault technology High cost Low recovery efficiency	Yes
	ExxonMobil Electrofrac™ Process	Improves porosity Rapid heating	High power consumption Pollute groundwater	No
	IEP's Geothermic Fuels Cells Process	Uniform heat Energy self-sufficiency	Complex, multi-fault technology High costs, low economic efficiency	No
Fluid heating process	American Shale Oil (AMSO) Process	high heat efficiency energy self-sufficiency	Easy short-circuit difficult to control Technology complex, high cost	No
	Chevron's Crush Technology	Improves porosity Low cost	Cracks easily closed	No
	Petro Probe Process	Energy self-sufficiency Can develop deep oil shale	Easy to short-circuit, difficult to control Difficult to control air flow	No
	In-Situ Gas Extraction Technology	Low cost Little pollution Can develop deep oil shale	Complex technology	No
Radiation heating process	Radio Frequency/ Critical Fluid Oil Extraction Technology	Rapid heating High recovery efficiency	Complex, multi-fault technology Pollute groundwater	No

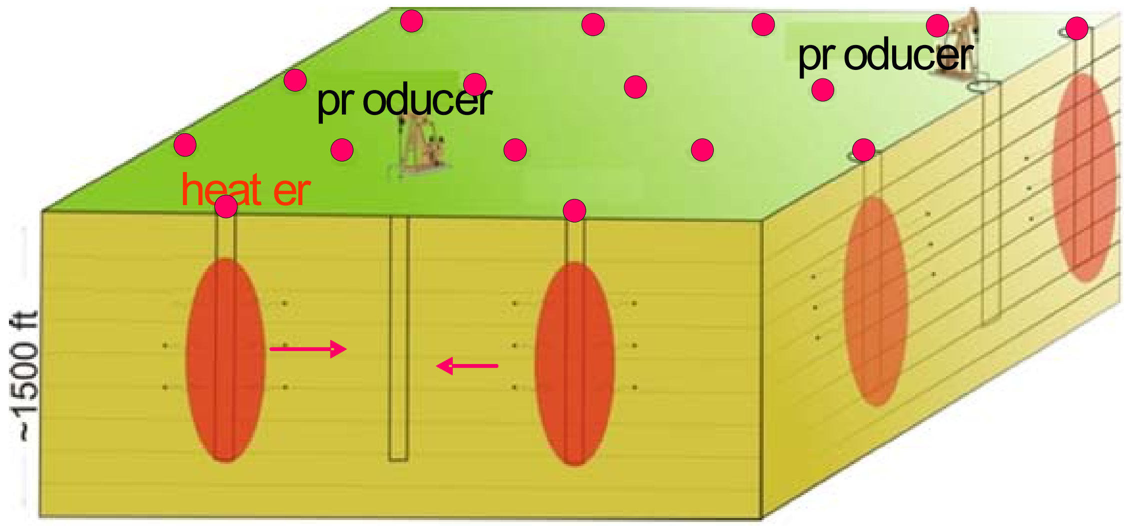

Figure 1: In-situ production by direct well electric heating

ally not be closed; the output of oil and gas production should be faster, but the fluid flow will be difficult to control and easy to short-circuit. Radiation heating technology is characterized by high heat penetrating power, resulting in faster heating, but is a complex technology, with multiple failure mechanisms, and considerable potential to pollute groundwater.

Research progress on in-situ conversion process in China

In 2007, PetroChina Company Limited began to study in-situ conversion process technology. PetroChina's well drilling and completion techniques, including those for vertical fracturing of reservoir rock have already matured. China's oil shale resource

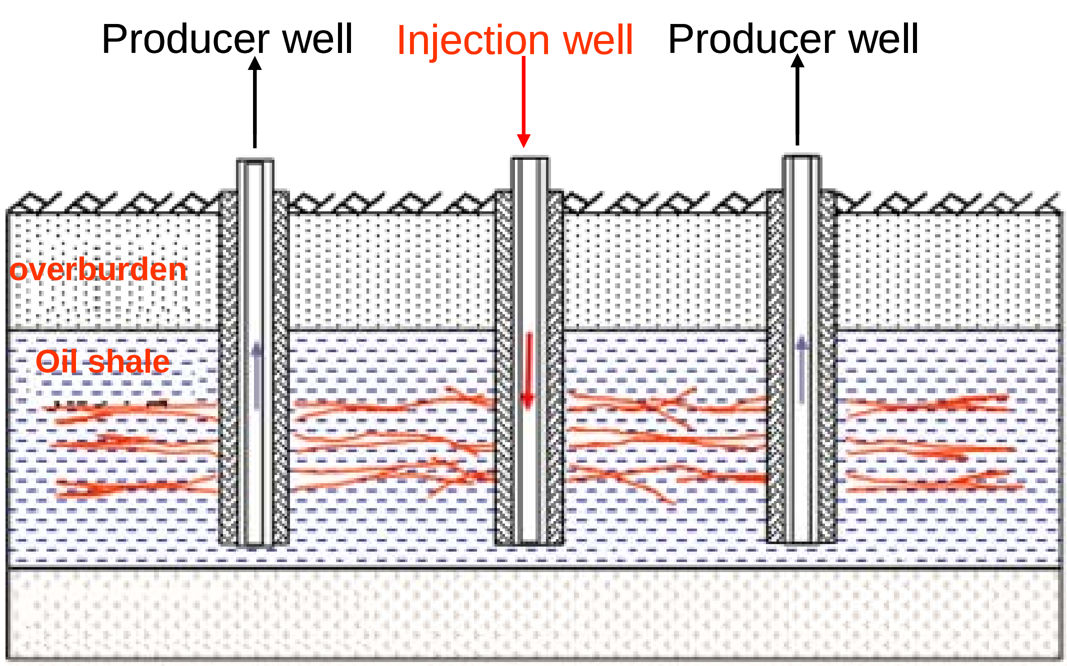

Figure 2: In-situ production by vertical well fracturing and injection of high-temperature gas for heating

is mainly distributed near major oil fields, convenient conditions for providing electricity and high-temperature steam to fully take advantage of in-situ conversion process technology from different companies. PetroChina designed a vertical well, electric heating program and a vertical well fracturing and high-temperature gas injection heating program.

In recent years, Petrochina has done a great deal of work on the principles of thermal fracturing. From these experiments, we can see that, due to the uneven thermal expansion, the density oil shale can produce a large amount of thermal fracturing along depositional bedding of oil shale by high temperature dry distillation (Figure 3). The fracturing heat induced fracturing enables more rapid production of the shale oil.

When the temperature is below 300 °C, we can see a very small number of smaller micro-cracks, which are produced in primary bedding mainly and around hard mineral particles; the fracture plane is parallel to bedding.

When the temperature exceeds 300 °C, it was observed that the number, length and width of cracks all increases substantially, a typical characteristic of thermal fracturing of oil shale. Thus we can see a very large number of micro-cracks formed perpendicular to bedding. Small cracks and large cracks are connected to form a network structure that improves oil shale permeability. (Figure 4)

Figure 3: a) original sample; b) post-retorting sample

In 2008, Petrochina designed a model of the electric heating in-situ conversion process. (Figures 5 and 6)

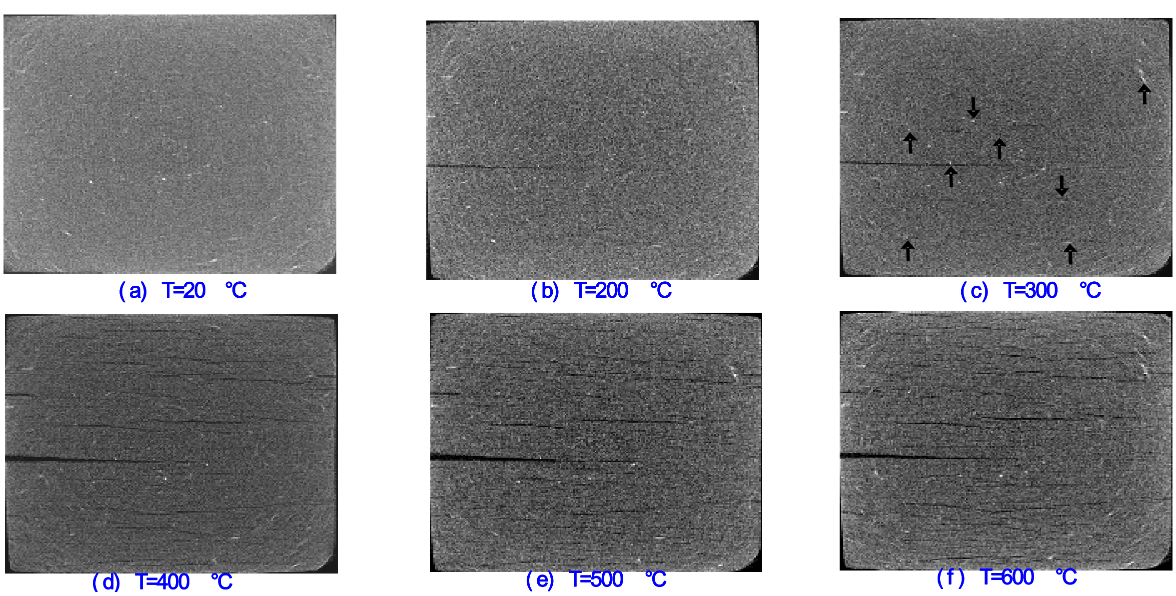

Figure 4: The fracturing behavior varies with temperature

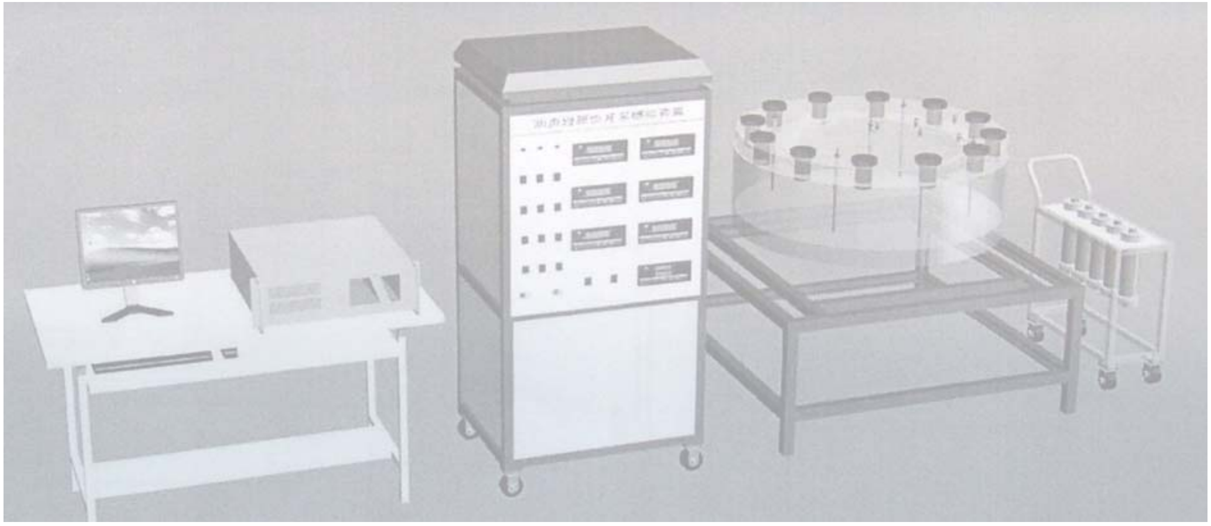

Figure 5: The model of an electric heating in-situ conversion process

Technical Parameters:
Dimension of inner cavity: ~1600×400mm
Working temperature: 20°C ~650°C
Voltage:220V
Power:10KW
Working pressure:0~40MPa

Function: Simulating underground trans-

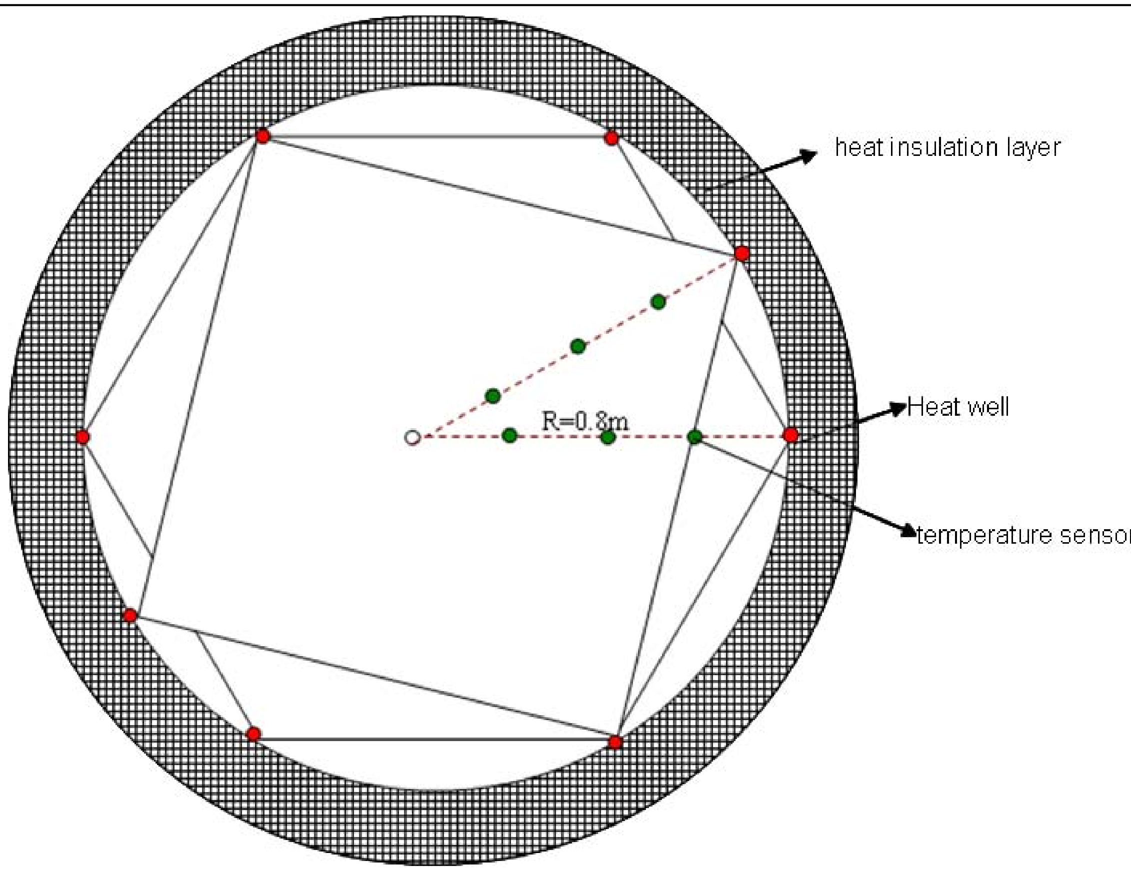

Figure 6: Distribution of heating rods and temperature sensors

formation process of oil shale.

Important Elements: Simulation System, Support System, Measurement System, Data Acquisition and Processing System, Control System, Safety Protection System and Condensing System.

Conclusions

1. Oil shale has a very important role as a supplementary energy source, but traditional energy use of oil shale has serious technical, economic and environmental problems in China that have slowed its industrial development.
2. The world's top oil companies have put technology development and innovation for in-situ conversion processes in a very important strategic position, and have spent a lot of human, financial and material resources for technical research and development.
3. Shell ICP technology has been at the forefront of other companies; the success of the company's field test is of great significance. It shows that the in-situ conversion process is an effective means of current development of oil shale. At present the key to the in-situ conversion process is how to further reduce costs and how to further protect the environment (especially the quality of groundwater).
4. The development and innovation of heating technology for in-situ conversion processes will continue more and more with rising oil prices.

References

Bunger, James W., Peter M Crawford, Harry R Johnson (2004) Is oil shale America's answer to peak-oil challenge [J]. Oil & Gas Journal, 2004, 8: 16-24.

HE Yong-guang, SONG Yan (2005) Comprehensive utilization of oil shale [J]. Coal Processing & Comprehensive Utilization, 2005, 1: 53-56.

LI Dan-mei, TANG Da-zhen, YANG Yu-feng (2006) Advances in oil-shale resources: development and utilization[J]. petroleum exploration and development, 2006, 33(6): 657-670.

Qian Jialin, Wang Jianqiu (2007) Current Status of World Oil Shale Development [J]. China foreign energy, 2007,12(1):7-11.

Shell Frontier Oil and Gas Inc. (2007) Technology to secure our energy future-mahogany research project [EB/OL] [2007-02-15].

Shell Frontier Oil and Gas Inc. (2006) E-ICP project plan of operation-oil shale research and development project[R]. Houston: Bureau of Land Management U.S. 2006.

U.S. Department of Energy (2007) Secure Fuels from Domestic Resources: The Continuing Evolution of America's Oil Shale and Tar Sands Industries[R]. 2007.07

YAN Che, and JIANG Xiu-min (2000) Research on energy resources utilization of oil shale in China [J]. Energy of China, 2000 (9):22-26.