

# Freeze-hole construction technology applied to in situ mining for oil shale

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## **Abstract**

This paper briefly introduces the application of the freezing technology in the field of oil shale mining and the principle of the freezing technology. It also describes different characteristics of application for in situ mining for oil shale from other of underground works for the freeze-hole technology as well as the risks inherent in this technology. The operational parameters for the freezing technology also need to be studied in depth. As for the broad applicability of the freeze-hole technology, the freezing technology would be applied to the exploitation in other fields of new energy.

Keywords: freezing technology; oil shale; exploitation.

## **Introduction**

Oil shale, as an important complement to energy resources, with its enormous reserves and the level of the rich utilization, has been concerned by the whole world. According to the current amount of global oil shale resources, if converted it into shale oil, the amount could reach to 4 000 billion tons, which is more than the amount of oil resources (reserves of 150 billion tons, the total resources of 300 billion tons) [1, 2]. In recent years, the problem of insufficient oil supply has been intensified, which had severely restricted the speed of economic development in China [3]. Thus, the development and utilization of oil shale has great significance in the mitigation for the domestic supply of oil and gas.

Traditional mining model for oil shale is generally mined by open or roadway mining. However, the traditional mining model for oil shale made oil shale underutilized and brought rather serious environmental pollution. After years of research, in situ mining for oil shale has been gradually formed, which is more economical and more environmentally friendly.

The problem of cutting off groundwater has been the key to in situ pyrolysis for oil shale. While the freezing technology can precisely solve this critical issue. A secure and reliable ice wall established can provide protection for high-temperature extraction for oil shale smoothly under the conditions of in situ water.

## **Applications of the freezing technology in the field of oil shale mining**

Currently, the freezing technology has steadily developed toward the field of new energy, which also had taken place in the field of oil shale mining.

In the 2006, a plan which was called as electric heating in situ mining technology (referred to as E-ICP) by Shell was used to the new round of in situ mining for oil shale as a pilot program in the mining site. A total of 150 frozen wells around were drilled in the E-ICP project. And the interval of the two linked frozen wells is 3.44 m, the depth of the freezing well is about 609 m [4].

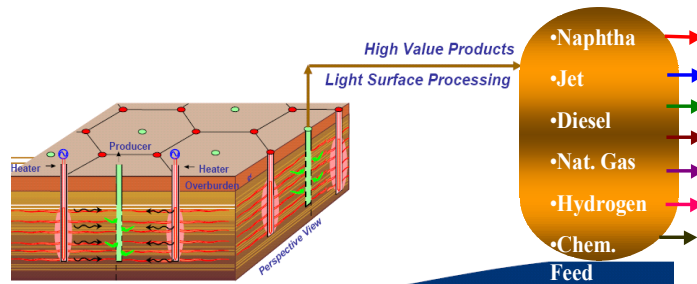


Figure 1 ICP Technical Chart of Shell

The frozen wall in the ICP technology was formed by frozen wells, and closed pipe networks which connected the freezing wells, as well as the frozen wallrocks. A series of drills whose interval was about 3 metres were drilled around the test mining area. Then, a closed loop system was chilled into the frozen well. Finally,  $-45^{\circ}\text{C}$  frozen liquid circling in a closed loop system was poured into the circulatory system, making the groundwater around the system and the wall rock medium frozen together to form a freeze wall.



Figure 2. Three-dimensional renderings of the frozen wall  
1 – Earth's surface; 2 – Frozen wall; 3 – Frozen Well; 4 – Oil shale

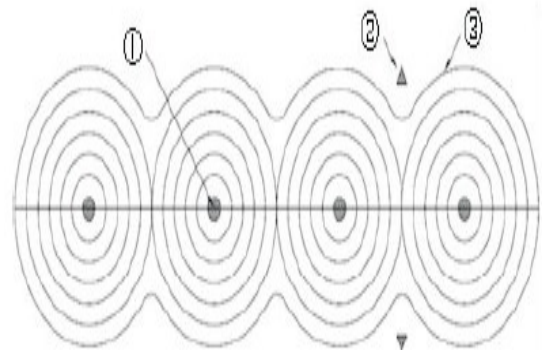


Figure 3. The surface effect of frozen wall  
1 – Frozen Well; 2 – Monitoring wells;  
3 – Frozen wall.

The idea that the ice wall was brought into the ICP technology was to prevent the ground water into the heating zone to result from oil gas leak. It was in order to promote the mining model for oil shale toward a newer and more environmentally sustainable development path with steady progress.

In 2010, freezing technology has been fully applied in the Country's Potential Oil and Gas Resources Project (Development and Utilization of Oil Shale Exploration). A series of tests of in situ mining for oil shale have been carried out in the mining site. The purpose of cutting off the ground water was

achieved through the freezing technology. The designed interval between the frozen holes was from 0.8 to 1.6m and the depth of freeze well was about 500 metres.

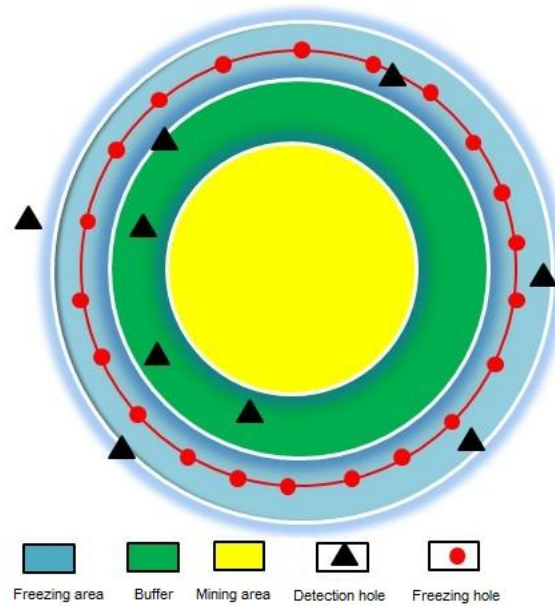


Figure 4. The layout of frozen holes

### The principle of freezing technology

Artificial freezing technology is through the way of decreasing of soil temperature to gradually form natural moisture content of soil into freezing of body. It is through its increased strength and stability to resist stress and pressure from the underground and cut off the links between groundwater and underground structures. It is a special technology in order to proceed smoothly under the protection of frozen wall to complete the excavation of tunnels, shafts and foundation and lining construction projects [5]. The essence of the technology is to use the artificial refrigeration technology to change the mode of rock temporarily [6].

Freezing method is to continuously import the cryogenic liquid (salt or low-temperature liquefied gas) through the frozen pipes (steel tube) buried in the ground, thus cooling the ground surrounding frozen pipes, so that making the pore water existed in the soil into ice decreased to below 0°C.

### The main features of freezing technology for oil shale drilling

Compared to freeze technology in other underground engineering, the freezing technology applied in the field of in situ mining for oil shale still needs some special requirements.

The main features of freezing technology for oil shale drilling are as follows:

(1) The vertical require for freeze holes is very high (less than 5 %).

The deflection of freeze-hole would seriously affect the circling time of the frozen wall at the bottom of the freeze-hole. Therefore a special high-precision measurement MWD tool is needed to be used.

(2) The layout of freeze-hole is more flexible and easily to control.

According to different geological conditions, environmental and site conditions, freeze-holes could be flexibly arranged and the temperature of the refrigerant could be regulated, thus to obtain frozen soil with high quality [7].

(3)The requirements of the frozen soil is relatively high.

It is the key to cut off groundwater for in situ mining for oil shale. Therefore a continuous dense impermeable frozen wall need to be made which is to cut off the groundwater contact. It is tried to ensure that oil shale is proceeded high-temperature mining under the conditions of in situ water.

(4)The winter cooling and the summer cooler are required to combine.

Unlike the freezing technology applied in other underground works, in situ mining for oil shale is required relatively long times. It is often required to change across several summers and winter. So the winter cooling and the summer cooler are required to combine.

### **The risks existed in the freezing technology**

The freezing technology has its own particularity. Because of the existence of its characteristics, as for the freezing technology, some accidents are likely to be caused in the process of freezing-hole drilling, and freezing , as well as thawing permafrost. Therefore, the freezing method is a high-risk technology so that the slightest mistake will lead to major accidents. For example, the running tunnel was between "Forest" station and "heroic Square" station in Metro Line 1 of St.Petersburg , whose groundwork was reinforced by freezing technology, which is through the ancient Neva river. However, when the tunnel was bored, the unfrozen areas were excavated. As a result, a major accident of submerged tunnel was caused<sup>[8]</sup> . Shanghai Metro Line 4 which was across the Huangpu River. In the construction of contacting channel with the freezing method, a serious accident that the two-tube tunnel collapse occurred was caused by a variety of reasons [9]. Major types of accidents caused by risks in the application of freezing technology are as follows:

(1)The accident of freeze hole drilling

When the orifice seal is failure, water and sand blasting will be caused. When it is serious, deformation and failure of underground structures will be caused by excessive losses of formation .

(2)The accident of the damage to the segment

It is generally divided into two cases. One is that large damage to the segment is caused by drilling and the other is that when removal of part of the segment. The deformation segment is too large or even unstable caused by the loss of integrity of the ring segment.

(3)The accident of the frozen wall

The instability of frozen wall will lead to flooding incidents and quicksand, as well as the deformation, and failure of underground structures when it's severe. Accidents of frozen curtain can be summarized into four main areas: geometry defects, and physical defects ,as well as misjudgment of characters of frozen curtain , also including improper construction management [9].

(4)The accident of frost heave phenomenon

Frost heave phenomenon will cause broken frozen pipes and deformation accident of underground structures.

(5)The accident of thaw phenomenon

Thawing permafrost phenomenon will cause differential settlement of underground structures, which would result in structural deformation, or cause the destruction of ground construction , and underground structures as well as pipeline.

Through the analysis of riss of freezing technology, it can help to keep the development and improvement of freezing technology, in order to apply to a wider range of new energy sectors.

## Conclusion

- (1) It is the core to cut off the groundwater for in situ mining for oil shale, thus the further research of the diameter and depth of freezing-hole and intervals of frozen pipes and other operating parameters is needed.
- (2) For the special applications of freezing technology for in situ mining of oil shale, unlike the applications of other areas, special requirements and strict control accuracy are needed. For special factors, the further study is needed.
- (3) Currently, the application of the freezing technology is just concentrated in the areas of coal drilling, which is the preferred technology for special shaft construction. While the freezing technology applied in the field of oil shale also makes oil shale mining technology towards the new environment-friendly concept further.

It also promoted the technology to the development and application of other areas of new energy more extensive further.

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#### **Анотація**

Стаття коротко описує вживання і принципи технології заморожування на полі видобутку горючих сланців. Також описуються різні характеристики вживання свердловинного видобутку горючих сланців порівняно з підземними технологіями, а також пов'язані з цим ризики. Робочі параметри технології заморожування вимагають додаткового дослідження. Для розширення сфери застосування технологія заморожування буде застосована на інших полях видобутку..

Ключові слова: технологія заморозки, горючий сланець, експлуатація.

#### **Аннотация**

Статья кратко описывает применение и принципы технологии заморозки на поле добычи горючих сланцев. Также описываются различные характеристики применения скважинной добычи горючих сланцев в сравнении с подземными технологиями, а также связанные с этим риски. Рабочие параметры технологии заморозки требуют дополнительного исследования. Для расширения области применения технология заморозки будет применена на других полях добычи.

Ключевые слова: технология заморозки, горючий сланец, эксплуатация.