IMPROVEMENT OF URANIUM PRODUCTION EFFICIENCY TO MEET CHINA'S NUCLEAR POWER REQUIREMENTS

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Abstract

Recently China put the Qinshan Nuclear Power Plant, with an installed capacity of 300 MW, in the province of Zhejiang and the Daya Bay Nuclear Power Plant, with a total installed capacity of 2 × 900 MW, in commercial operation. China plans a rapid growth in nuclear power from 1995 to 2010. China's uranium production will therefore also enter a new period with nuclear power increasing. In order to meet the demand of nuclear power for uranium, special attention has been paid to both technical progress improvement using management with the aim of reducing the cost of uranium production. The application of the trackless mining technique has enhanced the uranium mining productivity significantly. China has produced a radiometric sorter, model 5421-2 for pre-concentrating uranium run-of-mine ore. This effectively increases the uranium content in mill feed and decreases the operating cost of hydrometallurgical treatment. The in situ leach technique after blasting is applied underground in the Lantian Mine, in addition to the surface heap leaching, and has obtained a perfect result. The concentrated acid-curing, and ferric sulphate trickle leaching process, will soon be used in commercial operation for treating uranium ore grading −5 to −7 mm in size. The annual production capability of the Yining Mine will be extended to 100 tonnes U using improving in situ leaching technology. For the purpose of improving the uranium production efficiency much work has been done optimizing the distribution of production centres. China plans to expand its uranium production to meet the uranium requirements of the developing nuclear power plants.

1. INTRODUCTION

Recently the nuclear power of the mainland of China put the first self-designed and self-constructed Qinshan Nuclear Power Plant in Zhejiang province with 300 MW(e) and the largest joint venture project, Daya Bay Nuclear Power Plant, in province Guangdong, with 2 × 900 MW(e), in commercial operation. China plans a fast growth of nuclear power in the period from 1995 to 2010. New power reactors totalling 10 GW(e) will be under construction in 2000. The key nuclear power plants will be concentrated in the coastal areas, where the economy develops faster, and there is a lack of primary energy resources. The construction of the second Qinshan NPP project with 2 × 600 MW(e) has been started. The second Daya Bay NPP with 4 × 1 GW(e) located in Ling'ao near Daya Bay will be constructed in two phases. The active preparation work for construction of the first phase project with 2 × 1 GW(e) sets is under way. For the third NPP of Guangdong province, the site has been basically planned in Yangjiang. The site selection for NPP with 4 × 1 GW(e) in Liaoning province has been approved. It will be located in Wafandian. Its feasibility study is carried out by both China and Russia. The Sanmen NPP with 4 × 1 GW(e) will be constructed in two phases Sanmen county, Zhejiang province. In addition, the earlier stage work on construction of nuclear power plants will be developed for Shandong, Jiangsu, Fujian, Hunan, Jiangxi and Jilin provinces.

Specialists believe that the rapid period of development China's nuclear power will be round the year 2010. The installed nuclear generating capacity will reach 20 to 30 GW(e) by 2010.

China follows the policy of "self-sufficiency of uranium" for nuclear power plants. China's uranium production will therefore also enter a new historical period with rapid development of nuclear power. In order to meet the demands of uranium for nuclear power, China's uranium industry must provide at least 3500 tonnes uranium each year before 2010. This is a promising future for China's uranium industry. In recent years, special attention has been paid to technical progresses, and the management has been improved, with the aim of reducing the uranium production cost and increasing the competitive ability of China's uranium production industry.

2. TRACKLESS MINING

The application of trackless mining has had a great effect on simplifying the mining process, resulting in higher efficiency. In China's uranium mining the trackless mining technique was started in the 1980s. It has industrial application at Quzhou Uranium Mine. Several years practice at Quzhou Uranium Mine demonstrated its advantages over the traditional mining system.

TABLE I. COMPARISON OF TRACKLESS MINING WITH TRADITIONAL MINING METHOD IN QUZHOU URANIUM MINE

Items	Traditional	Trackless
Height of mining level	25 m	50 m
Stope area	300–500 m^2	500–1000 m^2
Annual output each stope	8000 t	15 000–35 000 t
Operating staff	100%	40–60%
Ore loss and dilution	100%	70–90%
Operating cost	100%	85.5–60%

The trackless mining technique has been planned to be adopted for the existing Renhua Uranium Mine and the new Benxi Mine.

3. RADIOMETRIC SORTING

The new radiometric sorter has also produced good results.

The radiometric sorters have been adopted in uranium production since first China's uranium mine was constructed. By eliminating waste rock and below grade ores the consumption of chemicals and energy has been considerably reduced in uranium extraction process. To increase the sorting efficiency, the 5421 model radiometric sorter was developed and went to commercial operation in the 1980s. On this basis, the more advanced 5421-2 model radiometric sorter was developed in the 1990s. The 5421-2 sorter is a sorting system, consisting of one 4 channel unit processing 25–60 mm ore and one 2 channel unit processing 60–150 mm ore. The capacity of both units used together in a complete set can meet the demands of a uranium mine's sorting plant with a capacity of 150 000 t per year. The main technical specifications are shown in Table II.

TABLE II. TECHNICAL SPECIFICATIONS OF 5421-2 MODEL SORTER

Size, range, mm	60–150	25–60
Capacity, t/h	26–31	14–17
Sorting efficiency, %	>90	>80
Sorting sensitivity, mg (U)	<55	<15

The 5421-2 model radiometric sorter employs a computer for the controlling process. Multiple scintillometers are used to detect ore by relay mode. Other advanced techniques, such as mathematical statistics and digital computation are also adopted in the sorter. This sorter has the advantages of higher sorting sensitivity and efficiency, higher capacity and better automation. The sensitivity range of uranium grade can reach ± 10 ppm at a certain cut-off grade.

The use of two 5421-2 model sorters in the sorting plant of Fuzhou Uranium Mine simplifies the process flowsheet. The 11 old sorters were replaced, and operating personnel was decreased. The operating cost was reduced by 10%.

4. IN-PLACE LEACHING AFTER BLASTING

In-place leaching after blasting was first applied at the Lantian Uranium Mine. Heap leaching is a comparatively low cost processing method and has wide industrial application at China's uranium mines. In-place leaching after blasting has been successfully put into operation at Lantian since 1990. In place leaching after blasting is a mining system consisting of the underground blasting of hard and compact orebody, reducing the ore to the desired size and permeability. The leaching agent, is then added selectively recovering useful metal from the ore. Compared with the traditional mining and metallurgical technology, this method has advantages of higher efficiency, lower cost of production, safe operation and environmental benefits. It is applicable to orebodies with easily leached property of the desired metals.

In-place leaching after blasting was carried out at orebody No.30. It occurred in a tectonoclastic zone of fractured granite, with a density of 2.48 t/m^3, and the average thickness of 6.59 m. The top of the body was close to the surface, and the hydrogeological condition was simple. The geological reserve was 7160 t of ore with a uranium content of 0.171%.

The sublevel caving and shrinkage system was adopted. At the bottom of the body liquor collecting tunnel was developed. In the entire mining area, four blasting sublevels with the height of 10–16 m for downward blasting were arranged. The barrage-type distribution was adopted as the main mode, and the trickling distribution and injection through wells as a subsidiary one. Usually the liquor is well distributed and the leaching was relatively complete. An average uranium content of 0.014% was obtained in residue, with the uranium recovery 88.98% and the utilization coefficient of mineral resources of 83.43%. This method will be applied to other orebodies.

5. CONCENTRATED ACID CURING AND FERRIC SULPHATE TRICKLE LEACHING

The method of uranium recovery using concentrated acid curing and ferric sulphate trickle leaching uranium process is adopted in production. Grinding is an indispensable operation in the traditional hydrometallurgical processing of uranium ore. Its proportion of cost in ore processing is great. The energy consumption of grinding usually accounts for 30% to 50% of the total. In the late 1980s, we started investigation on concentrated acid curing and ferric sulphate trickle leaching process (NGJ process, N, G and J — the first letters of concentrated, ferric and leaching in the Chinese alphabetic system of writing respectively. The process includes ore crushing (up to 5–7 mm), concentrated acid curing, ferric sulphate leaching, tertiary amine solvent extraction, product precipitation and residue disposal with the process effluent in a closed circuit. Four of China's typical uranium ores were studied using the NGJ process and compared with the traditional agitation leaching (AL) process (see Table III). Either for soft sedimentary type uranium ore or for hard and tight volcanic type ones, leaching results indicate that the NGJ process has advantages over AL process.

TABLE III. COMPARISON OF LEACHING RESULTS BETWEEN NGJ AND AL PROCESSES

Ore		NGJ process			AL process		
Ore	U grade	Operation condition		Recovery %	Operation condition		Recovery %
		Size mm	H_2SO_4 %		Size mm	H_2SO_4 %	
Sedimentary	0.126	-5.0	9-10	90.5	-0.5	13-14	90.0
Volcanic (rhyolite)	0.0815	-5.0	1.5-2	88.1	-0.25	5-6	90.5
Granite	0.56	-5.0	5.6	98.0	-0.5	6-9	98.2
Quarzite	0.10	-5.0	5	91.0	-1.0	7	93
	0.43	-3.0	5	97.0	-0.32	5.6	96.5

In 1993, an industrial experiment was carried out for the sedimentary type uranium ore. It was steadily operated for 92 days with 726 tonnes ore treated and 500 kg sodium diuranate produced. The extraction rate reached the level of the AL process, when the ore size was less than 7 mm, and the trickle leaching cycle was 10 to 45 days. The NGJ process is simple and its operation is stable. Compared with the AL process (see Table IV), the process effluent discharge is eliminated and most of the residue can be used for backfill in mine.

TABLE IV. SOME ECONOMIC COMPARISON BETWEEN NGJ AND AL PROCESSES

Items	AL process	NGJ process
Power	1	1/3
Water	1	1/20-1/10
Operating costs	1	0.4-0.55

It can be concluded that the NGJ process is an intensified heap leaching operation. The practice shows that the NGJ process is a very effective extraction method for some of China's uranium ores. The method if of important significance in China's uranium ore processing.

6. IN SITU LEACH MINES

The Yining Uranium Mine is reaching one hundred tonnes annual production capability using in situ leach technology. A small scale production of in situ leaching is being successfully carried out at Deposit No. 512, Yining Uranium Mine, Xinjiang Uygur Autonomous Region, and useful experience has been obtained. Now the larger project is being developed.

7. REORGANIZATION AND MANAGEMENT OF URANIUM PRODUCTION

Beside the technical progresses obtained in uranium mining and metallurgy, a series of adjustments and reformation measures have been adopted over the last decade to conform to the requirements of a market economy. The first adjustment was cutting back uranium production and the closure of uranium mines and mills that had comparatively high production costs. The remaining operating uranium production enterprises must, according to the product price, define proper cut-off grade of uranium ore and decrease ore dilution. They must reduce also the workforce, and reduce material and energy consumption.

Another important adjustment is to pursue diversified economy while maintaining uranium industry as the main objective. All the enterprises and institutions of the uranium industry have been energetically developing non-uranium products and techniques. Significant results have already been achieved. To date, the equivalent of about 200 millon US Dollars has been invested and the non-uranium development has started producing the following main products: titanium pigment, magnesium metal, rare earths, ordinary phosphorus, etc. A total of 25 000 employees from uranium production have been transferred to diversified projects. It is evident that under the China's specific economy system non-uranium production improves uranium production efficiency.

We believe that in the coming 15 years China will have a stable and rapid development in the uranium industry to meet the requirements of nuclear power for uranium.