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Executive summary

China currently has numerous research reactors that may contain small amounts of graphite, with the exception of HTR-10 which contains about 65 tonnes. As the HTR-PM reactors come on line, the graphite waste inventory will increase significantly. The first pair of HTR-PM reactors will contain about 1000 tonnes of graphite. North Korea has the now-closed 5MWe Pyongbyon research reactor. Any reference to the volume of graphite for this plant has been found. The second 50MW reactor similar to a Magnox was not completed but this would have been significant, but is not irradiated.

Revisions

Rev.	Date	Short description	Author	Internal Review	Task Leader	WP Leader
01	20/01/2009	Draft issue 1	H Eccles (UK NNL)	M Metcalfe (UK NNL)	H Eccles (UK NNL)	H Eccles (UK NNL)
02	21/03/2009	Issue 1	H Eccles (UK NNL)	M Metcalfe (UK NNL)	H Eccles (UK NNL)	H Eccles (UK NNL)

Chapter contents

1 Introduction

This chapter considers the nuclear reactors in three Asian countries, China, North Korea (Democratic People's Republic of Korea [DPRK]) and South Korea. Although these three countries particularly the first and last have invested heavily in nuclear power reactors there only a few cases where these are graphite moderated and of a demonstration size. Where appropriate reference to topics that are pertinent to irradiated graphite waste management are provided. Currently there are no indications that graphite retrieval and subsequent disposal even for these demonstration reactors is under consideration.

2 China

2.1 Legislative and Regulative Framework[1]

Ministries and Commissions are at the top level under the State Council, Administrations and Bureaus.

Under the State Council of Ministers, the China Atomic Energy Agency (CAEA) is responsible for planning and managing the peaceful use of nuclear energy and promoting international cooperation. Since being split from the old CNNC in 1998, the CAEA has been the key body planning and managing civil nuclear energy and reviewing and approving feasibility studies for new plants. The CAEA is under the control of the Commission for Science, Technology & Industry for National Defence under the State Council.

The State Nuclear Power Technology Corporation (SNPTC) was set up in 2004 to take charge of technology selection for new plants being bid from overseas. This is through its Preparatory Office which draws expertise from other organizations such as China Guangdong Nuclear Power Group (CGNPC). SNPTC is directly under China's State Council and closely connected with it. Early in 2007 Shanghai Nuclear Energy Research and Design Institute (SNERDI) (see below) was removed from China National Nuclear Corporation (CNNC) control and assigned to it as an R&D arm, boosting its stature considerably.

The National Nuclear Safety Administration (NNSA) under CAEA was set up in 1984 and is the licensing and regulatory body which also maintains international agreements regarding safety. It now reports to the State Council directly.

The State Environment Protection Administration (SEPA), now elevated to a Ministry of Environmental Protection, is a department directly under the State Council and is responsible for radiological monitoring and radioactive waste management. A utility proposing a new plant submits feasibility studies to the CAEA, siting proposals to the NNSA and environmental studies to SEPA.

The China National Nuclear Corporation (CNNC) controls most nuclear sector business including R&D, engineering design, uranium exploration and mining, enrichment, fuel fabrication, reprocessing and waste disposal. It also claims to be the major investor in all nuclear plants in China. Established by the State Council in 1988 as a self-supporting economic entity, it "combines military production with civilian production, taking nuclear industry as the basis while developing nuclear power and promoting a diversified economy". It has numerous subsidiaries.

China Power Investment Corporation (CPI, formed from the State Power Corporation and inheriting all its nuclear capacity) is a major power generator and is the largest state-owned nuclear power holding company.

2.2 Policy Objectives of Decommissioning[2]

The "Environmental Policy on Low- and Medium-level Radioactive Wastes Disposal" promulgated by the State Council in 1992, defined the roles radioactive waste management system and an environment supervision body. The corresponding organizations of nuclear safety, radiation protection, and environmental protection have been established in China's nuclear industry. China has enacted codes, standards, and guidelines for the management of radioactive wastes. In the development of the nuclear industry, necessary purification facilities for "three wastes" have been established.

China has not yet drawn up an overall plan for radioactive waste management. Moreover, the regulatory structure for radioactive waste management is not complete. Since nuclear power development in China began, low- and medium-level radioactive waste disposal sites have not yet been established. At present, this work is still in the siting and feasibility stage.

The problem of final disposal of radioactive waste has been left unsolved. Most nuclear incidents to date have been associated with the inappropriate treatment and disposal of radioactive wastes. The environmental impact of radioactive waste disposal has not been fully evaluated, and waste management is lacking.

2.3 Decommissioning of Nuclear Reactors – Current Situation[1]

Mainland China has eleven nuclear power reactors in commercial operation, a mix of PWRs, Pressurised Heavy Water Reactor (PHWR) and *Vodo-Vodyanoi Energetichesky Reactor*; *Water-Water Energetic Reactor* (VVERs), with a gross capacity of about 9,000 MWe. Seven more are under construction, and ten more about to start construction. Figure 1 illustrates reactor geographical location. In May 2007 the National Development and Reform Commission announced that its target for nuclear generation capacity in 2030 was 160 GWe. In March 2008 the newly-formed State Energy Bureau (SEB) said that the target for 2020 should be at least 5% of electricity from nuclear power, requiring at least 50 GWe to be in operation by then. In June 2008 the China Electrical Council projected 60 GWe of nuclear capacity by 2020.

The country aims to become self-sufficient in reactor design and construction, as well as other aspects of the fuel cycle.

Historically technology has been drawn from France, Canada and Russia, with local development based largely on the French element. The latest technology acquisition has been from the USA and France.

Apart from military facilities China has about 15 operational research reactors ranging in size from zero energy up to 15 MW, and one 125 MW light water High-Flux Engineering Test Reactor (HFETR) run by the (Southwest) Leshan Nuclear Power Institute of China at Jiajiang, Sichuan province, since 1979. Early in 2007, this was converted to use low-enriched uranium, with the help of the US National Nuclear Security Administration (NNSA). The 15 MW unit is a heavy water reactor which is the oldest, operating since 1958, and is under IAEA safeguards. Two further units of 60 and 65 MW are listed as under construction.

Figure 1: Geographical location of reactors[1]

The China Institute of Atomic Energy (CIEA) undertakes fundamental research on nuclear science and technology. Its 15 MWt heavy water research reactor started up in 1958 and was shut down at the end of 2007. CIEA is building the new 60 MWt China Advanced Research Reactor (CARR), a light water tank type unit which expected to start up in 2009, and also the sodium-cooled CEFR (see below).

A key R&D project is the demonstration Shidaowan HTR-PM of 200 MWe (two reactor modules, each of 250 MWt) which is being built at Shidaowan in Shandong province, driving a single steam turbine at about 40% thermal efficiency. The size was reduced to 250 MWt from earlier 458 MWt modules in order to retain the same core configuration as the prototype HTR-10 and avoid moving to an annular design like South Africa's PBMR.

The HTR-PM will pave the way for 18 (3x6) further 200 MWe units at a single site in Weihai city - total 3800 MWe - also with steam cycle. The Institute of Nuclear and New Energy Technology (INET) at Tsinghua University near Beijing is in charge of R&D, and is aiming to increase the size of the 250 MWt module and also utilise thorium in the fuel. Eventually a series of HTRs, possibly with a Brayton cycle directly driving the gas turbines, will be factory-built and widely installed throughout China.

A 65 MWt fast neutron reactor - the Chinese Experimental Fast Reactor (CEFR) - is under construction at China Institute of Atomic Energy (CIAE) near Beijing with some Russian assistance and it is due to achieve criticality in 2009. A 600 MWe prototype fast reactor is envisaged by 2020 and there is talk of a 1500 MWe one by 2030.

A 10 MWt high-temperature gas-cooled demonstration reactor (HTR-10)[Figure 2], having fuel particles compacted with graphite moderator into 60mm diameter spherical balls (pebble bed) was commissioned in 2000 by the Institute of Nuclear Energy Technology (INET) at Tsinghua University near Beijing. It reached full power in 2003 and has an outlet temperature of 700-950°C and may be used as a source of process heat for heavy oil recovery or coal gasification. It is similar to the South African PBMR intended for electricity generation. Graphite serves as a neutron moderator and reflector as well the main structural material of the reactor core, amounting in total to approximately 65 tonnes of graphite. Helium is the coolant gas.

3 Korea

3.1 North Korea

3.1.1 Legislative and Regulative Framework[3]

DPRK was a party to the Nuclear Non-Proliferation Treaty (NPT) as a non-nuclear weapons state, but it delayed concluding its safeguards agreement with the IAEA and in April 2003 it withdrew from the NPT. In October 2006 it exploded a nuclear device underground.
In February 2007 DPRK agreed to shut down and seal the Yongbyon reactor (Figure 3)and related facilities including reprocessing plant within 60 days and accept IAEA monitoring of this, in return for assistance with its energy needs. Further assistance would follow the irreversible disabling of the reactor and all other nuclear facilities.

3.1.2 Policy Objectives of Decommissioning

The policy objectives of decommissioning nuclear reactors are influenced by international agreements largely associated with non proliferation. At this stage no documents specifically relating to decommissioning policy can be found.

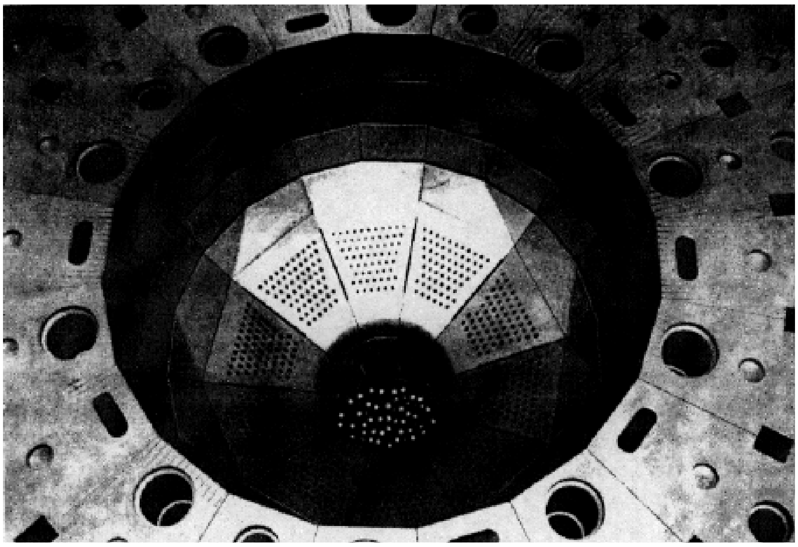


Figure 2: HTR-10[4]

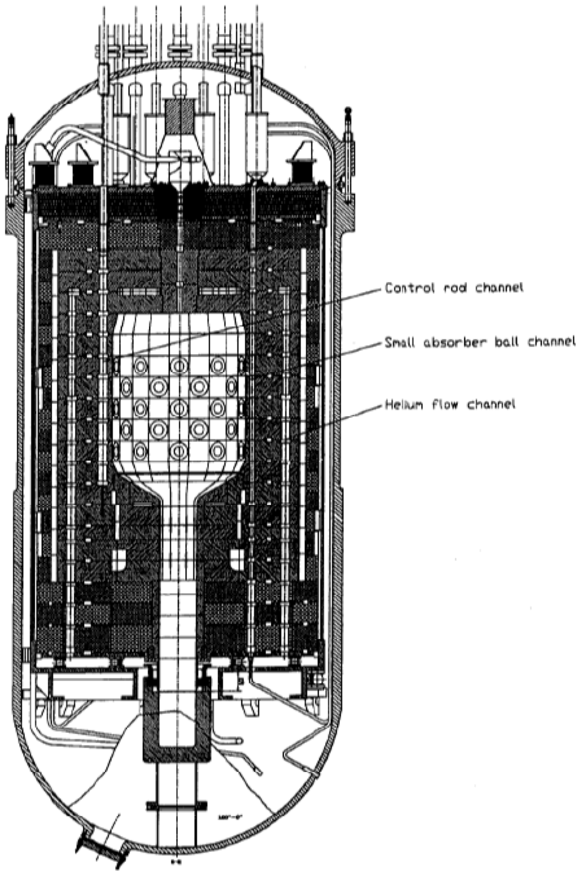
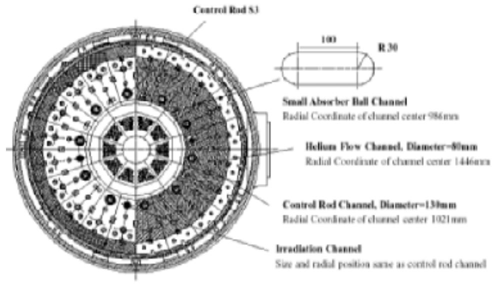


FIG. 4.6. HTR-10 reactor vertical cross-section.



3.1.3 Decommissioning of Nuclear Reactors – Current Situation[5]

The Yongbyon reactor is a gas-graphite reactor incorporating Magnox technology of some 25 MW thermal (5MWe) output which went into operation in 1986. The reactor has 801 channels for stacking fuel rods (10 fuel rods stuck in each channel) and for guiding control rods. Each fuel rod has diameter of 3cm and length of 50 cm.

North Korea operated the reactor for approximately seven years. It was shut down for between 70 to 100 days in 1989. It was operated for a further 30 days in 1990 and about 50 days in 1991. Under international agreement the facility was disabled in 2007.

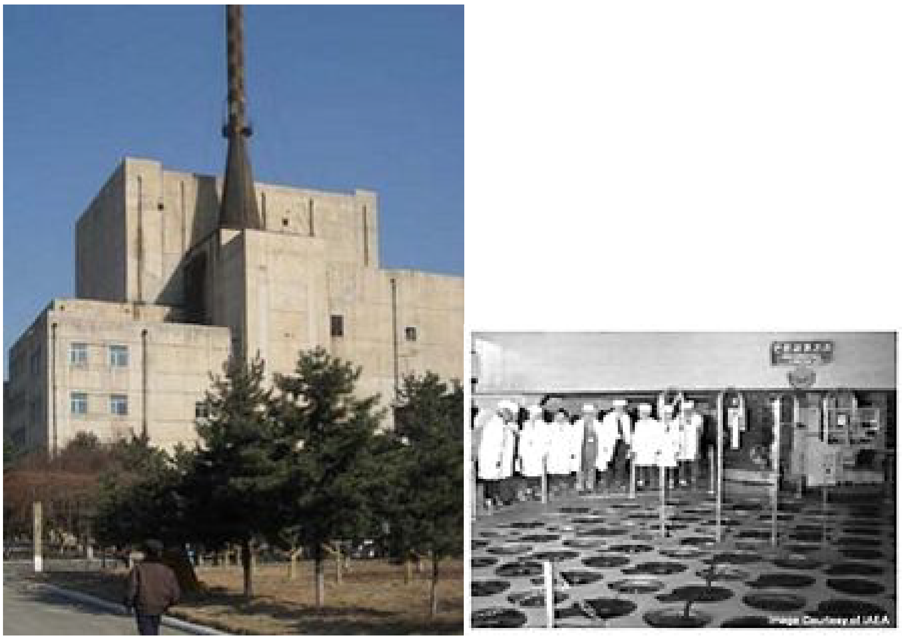


Figure 3: Yongbyon 5-MWe Reactor[3]

Yongbyon is also the site of a 50 MWe Magnox prototype power reactor that would potentially contain significantly more graphite. Construction was halted in 1994 about a year from completion in accord with the US-North Korea Agreed Framework, and by 2004 the structures and pipe work had deteriorated badly. By 2005, North Korea had redesigned the plant, so reconstruction ncould commence.

3.2 South Korea

3.2.1 Legislative and Regulative Framework[6]

In South Korea, nuclear-related activities are planned and carried out by various organisations, such as: the Atomic Energy Commission (AEC); the Nuclear Safety Commission (NSC); the Ministry of Science and Technology (MOST); and the Ministry of Commerce, Industry and Energy (MOCIE). The interactions are illustrated in Figure 4.

Under the Atomic Energy Act, the AEC is the highest decision-making body on policy issues and the utilisation of nuclear energy. The AEC is composed of nine to eleven members representing various sectors of the government, academia and industry. The chairman of the AEC is the Prime Minister.

The MOST has the overall responsibility for the nation's nuclear research and development, regulatory and licensing works. In order to deal with important issues in nuclear safety, the

NSC was established under the MOST in December 1996. The NSC consists of seven to nine members, including the Minister of Science and Technology who chairs the NSC.
The MOCIE is responsible for the construction and operation of nuclear power plants, nuclear fuel supply, and the management of low- and intermediate-level radioactive waste.

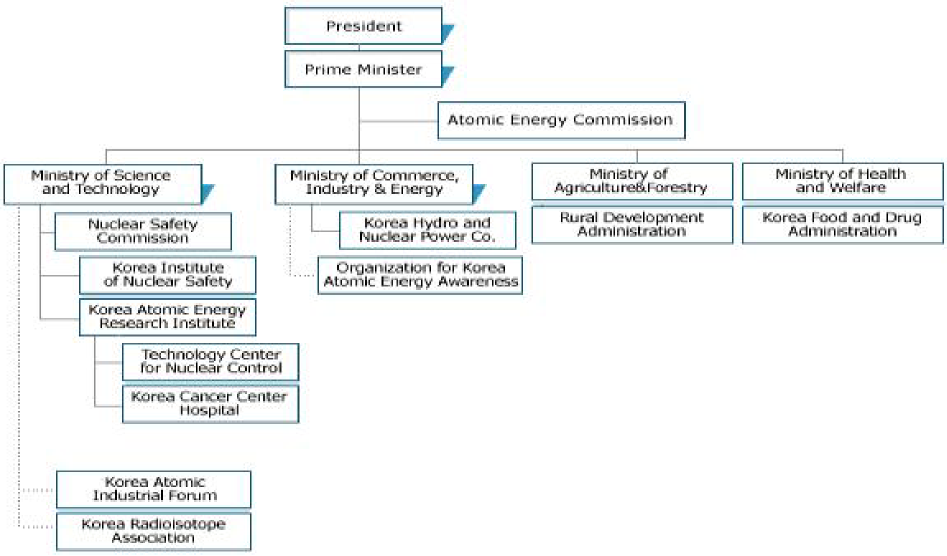


Figure 4: Main Nuclear-Related Organisations in South Korea[6]

3.2.2 Main national laws and regulations in nuclear power

- 1958 Atomic Energy Act and implementing texts and its 1994, 1996, and 1999 amendements;
- 1969 Nuclear Compensation Act, as last amended in 2001;
- 1971 Regulations on the Nuclear Installation Licensing System;
- 2004 Act on Physical Protection and Radiological Emergency.

3.2.3 Policy Objectives of Decommissioning[7]

Basic policy of the nuclear waste management:

- Management under government auspices; since radioactive waste needs long-term and safe management, the government takes total responsibility.
- Safety first; by safe management of radioactive waste for the preservation of the environment and the ecosystem and by abiding by international regulations on the safe

management of radioactive waste, any possible impact on human health and the environment is prevented.

- Minimisation of radioactive waste; South Korea strives to minimise radioactive wastes that result from nuclear power generation and radioisotope utilisation.
- Polluter pays principle; the necessary cost for management of radioactive waste is charged to the polluter from the time the pollution was generated, this therefore avoids passing the responsibility on to the next generation.
- Trust from general public; increase public acceptance and trust through the open and honest management of radioactive waste. The project will also contribute to community development.

3.2.4 Decommissioning of Nuclear Reactors – Current Situation4

As of December 2005, a total of nineteen nuclear power units are in operation, and eight units are under construction or in planning phase. All of these reactors are PWR, the first coming on-line in 1977.

To date South Korea therefore has no known i-graphite waste problem.

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[4] IAEA-ICTP Workshop on Nuclear Reaction Data for Advanced Reactor Technologies, ICTP – Trieste, Italy, 18-30 May 2008

[5] http://en.wikipedia.org/wiki/Yongbyon_Nuclear_Scientific_Research_Center

[6] NEA web site, Korea

[7] NEA web site, decommissioning in Korea