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The Korean Nuclear Power Program

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I. Introduction

Although the world nuclear power industry may appear to be in decline, continued nuclear power demand in Korea indicates future opportunities for growth and prosperity in this country. Korea has one of the world's most vigorous nuclear power programs.

Korea has been an active promoter of nuclear power generation since 1978, when the country introduced nuclear power as a source of electricity. Korea now takes pride in the outstanding performance of its nuclear power plants, and has established a grand nuclear power scheme.

This paper is aimed at introducing the nuclear power program of Korea, including technological development, international cooperation, and CANDU status in Korea.

II. Nuclear Power Development

Nuclear Power Status

Since the commercial operation of Kori Unit 1 started in April 1978, KEPCO, the sole electric utility in Korea, has achieved rapid growth in nuclear power development. Because natural resources are scarce in Korea, nuclear power has played a key role in the economic development of the country.

Korea now has eleven operating nuclear units which consist of ten PWRs and one CANDU. The latest unit is Yonggwang Unit 4 (1,000 MWe),

which was constructed in line with a nuclear technological self-reliance program. It began commercial operation in January, 1996, three months ahead of schedule. Yonggwang Units 3&4 were awarded the 1995 "Project of the Year Awards" by "Power Engineering International" magazine for their excellence in design, construction and operation. The nuclear capacity of the eleven operating units is 9,616 MWe, or 28.9% of the country's total installed capacity.

Table 1. Status of Operating Nuclear Power Plants

Plant		Reactor Type	Capacity (MWe)	Manufacturer		Commercial Operation
				Reactor	T/G	
Kori	Unit 1	PWR	587	W	GEC	Apr. 1978
	Unit 2	"	650	"	"	Jul. 1983
	Unit 3	"	950	"	"	Sep. 1985
	Unit 4	"	950	"	"	Apr. 1986
Wolsong	Unit 1	PHWR	679	AECL	NEI-Parsons	Apr. 1983
Yonggwang	Unit 1	PWR	950	W	W	Aug. 1986
	Unit 2	"	950	"	"	Jun. 1987
	Unit 3	"	1000	HANJUNG/CE	HANJUNG/GE	Mar. 1995
	Unit 4	"	1000	"	"	Jan. 1996
Ulchin	Unit 1	PWR	950	Framatome	Alsthom	Sep. 1988
	Unit 2	"	950	"	"	Sep. 1989

Seven additional units consisting of 4 PWRs and 3 PHWRs are now under construction, and 2 PWR units are in the planning stages. At the end of 1995, Wolsong Unit 2 was 84% complete, and is scheduled for completion in June 1997. Wolsong Units 3&4 in the same site obtained construction permits in February 1994, and will be completed in June 1998 and 1999, respectively. Ulchin Units 3&4 reached 65% completion with the construction of the main buildings for the reactor and turbine. In addition, construction permits for Yonggwang 5&6 were applied in August 1995, and invitations to bidding for Ulchin 5&6 were issued in June 1995.

Nuclear Power Operation

The performance of Korean nuclear power plants has shown remarkable improvement over previous years, and in comparison to the world

average. For example, in 1995, the average capacity factor for Korean nuclear plants was 87.3% while the world average was only 71.6%. Since 1991, the average annual capacity factor has been steadily maintained over the 80% level.

A comprehensive program is utilized to improve the plant capacity factor. Short-term efforts involve reducing unplanned plant trips caused by human error and equipment failure, shortening the refueling outage time period, and enhancing the quality of operating plants. Therefore, KEPCO has set a company-wide goal of "One Cycle Trouble Free" or "OCTF" operation. Due to several noticeable improvements, the number of unplanned trips has dropped. In 1995, there were a total of 11 unplanned trips, including three ones of Yonggwang Unit 3 during the first year of commercial operation, averaging 1.1 occurrences per reactor. Since 1988, when Kori Unit 3 achieved the first OCTF in Korea, "One Cycle Trouble Free" has not been unusual in Korea, and especially, had been recorded on three units among the then-operating nine units in 1993.

Additionally, in order to prevent unplanned shutdowns caused by human error, improvements were made through simulator training to enhance response ability against transient and abnormal operations. Furthermore, a Human Performance Enhancement System (HPES) was mobilized to find the root causes of plant malfunctions, and to educate operators and maintenance crews on how to avoid problems.

Long-term efforts include improving equipment and systems, operational management, and operational feedback in the design of plants under planning and construction. Also included is the adoption of an extended fuel cycle for PWR plants. A 15 month operating cycle from shutdown to shutdown for refueling has been applied to 600MWe class plants, and an 18 month fuel cycle for 950MWe class plants started in 1993.

On the other hand, the total average generation cost in 1995 was 86% of the 1986 level. This low price can be contributed largely to the expansion of the nuclear power program and improvements in nuclear power operation.

Long-term Power Development Plan

It is expected that annual growth rate of the demand for

electricity will average 8.5 percent in the short-term (1995 to 2000). The average growth rate from 1995 to 2010 is expected to be 5.9 percent per annum. Therefore, the power development program of 1995 stipulates the addition of new generating facilities of some 47,367 MWe by the year 2010. Among them, 17,713 MWe will come from nuclear energy. In the long-term nuclear power development plan, the Korean Standards Nuclear Power Plant (PWR, 1,000MWe) and the Korean Next Generation Reactor Plant (PWR, 1,300MWe) will be the major options, and a 900MWe PHWR will be alternatives. When the program is completed, the total installed power capacity should be 79,551 MWe.

The current capacity ratio among nuclear, fossil (coal, oil & LNG), and hydro sources is 29 : 62 : 9 respectively. This ratio will be 33 : 59 : 8 in the year 2010. The share of nuclear electricity production will increase to 46% in 2010 from the current level of 36% because nuclear power plants will serve to handle the base-load.

Table 2. Long-term Power Development Program

Unit : MWe, (%)

Source	1995	2000	2005	2010
Nuclear	8,616 (26.8)	13,716 (26.0)	18,716 (27.5)	26,329 (33.1)
Coal-fired	7,820 (24.3)	15,825 (30.0)	22,025 (32.4)	21,700 (27.3)
LNG-fired	6,736 (20.9)	14,201 (26.9)	16,214 (23.9)	22,014 (27.7)
Oil-fired	5,919 (18.4)	5,135 (9.8)	5,495 (8.1)	3,525 (4.4)
Hydro	3,093 (9.6)	3,878 (7.3)	5,483 (8.1)	5,983 (7.5)
total	32,184 (100)	52,755 (100)	67,933 (100)	79,551 (100)

Radioactive Waste Management

In 1988, the Korea Atomic Energy Commission established goals for radwaste management. The plans included construction of a final repository for low and medium level radwastes to be built by the end of 1995, and a centralized interim spent fuel storage facility (for both PWR and PHWR fuels) to be built by the end of 1997.

As in other countries, the radwaste plan had been beset by public opposition, which has slowed the timetable. Ending several difficulties in securing an appropriate site for radwaste disposal, the Korean government, in December 1994, officially announced that a small remote island, Kurrupdo, off the west cost of Kyunggi province was selected as the final candidate, and in February, 1995, the Korea Atomic Energy Commission has finally approved the island as the site for LLW.

However, more extensive geological surveys revealed at least two active faults within a few kilo-meters of the island that pose a significant earthquake risk. In the end, the Korean government has canceled plans to site a radwaste disposal on the island, and is reexamining its previous short list of sites.

Early this year, the Korean government made the decision that KEPCO should assume the major tasks of radioactive waste management program, taking into account KEPCO's capability of such mission. This decision involves appropriate rearrangement of institutional and legal framework for the program implementation.

Currently, more than 2,600 tones of spent fuel and 48,000 drums of low-level radioactive wastes are stored at reactor sites. KEPCO is undertaking several measures to increase storage capacities for spent fuel and radioactive wastes.

Ⅲ. Technological Development

Technological Self-reliance

Nuclear power experience in Korea can be classified into the following three stages. During the first stage of nuclear power in Korea, nuclear power plants were constructed on a "turnkey" basis. In turnkey construction, the reactor vendors were usually responsible for the entire project, from design, engineering and construction to the startup and turnover of the plant to the owner. The first three nuclear units were built on this "turnkey" concept.

In turnkey contracts, the opportunities for technology transfers were very limited. Also, participation of domestic companies was limited to site preparation work. In other words, Korean companies participated as subcontractors of foreign contractors to provide

small portions of field design, equipment supply and construction. In order to contribute to a more stabilized energy infrastructure, that was less reliant on foreign sources of energy, it was widely recognized that Korea should be as self-reliant as possible in nuclear power technology.

In the second stage of nuclear power, KEPCO took responsibility for project management along with direct procurement of the balance of the plant. Main contracts for supplying NSSS, T/G, and engineering services were made with foreign contractors. A Korean contractor took responsibility for the site construction, while other Korean companies were strongly encouraged to expand their roles in engineering service and equipment supply. The six units of 950 MWe were constructed under this approach, which significantly strengthened Korea's capability to deal with nuclear power projects itself.

The third stage of nuclear power development started with the aim of finalizing the nuclear technology self-reliance program. This program has been in effect since the construction of Yonggwang Units 3&4, with Korean industries as prime contractors. KEPCO has been in charge of project management and technology transfer. Several other domestic organizations have participated in plant design, construction and management, with assistance from foreign sub-contractors. All Korean organizations and entities which have participated in the nuclear power program have improved their capabilities through technical and on-the-job involvement in all disciplines of nuclear power technology.

On the other hand, KEPCO has driven the standardization of a nuclear power plant, pursuing technological self-reliance and localization. KEPCO has developed design basis of a Korean Standard Nuclear Power Plant (KSNP), reflecting the operating experience with the existing nuclear power plant and the proven technologies used in ALWR program in USA.

The commercial operation of Yonggwang Units 3&4 signified the beginning of a new era of technological self-reliance in Korea's nuclear industry. The Yonggwang Units will serve as basic models for the development of KSNP. The Korean Standard Nuclear Power Plant is now applied to construction of Ulchin 3&4 and Yonggwang 5&6. Also, it will be applied to subsequent PWRs including the two units in North

Korea, until the development of the Korean Next Generation Reactor.

KNGR Project

In 1992, the Korean government and KEPCO launched the Korean Next Generation Reactor (KNGR) project to develop a standardized advanced light water reactor, based on previous experience acquired through the KSNP's design and technological self-reliance program of 1987. The KNGR project's goal is to complete a standardized KNGR design by February, 2000. This project will be applied to the new nuclear projects which are anticipated to begin operation in 2007.

Because developing a new design for nuclear power plants requires a great deal of resources and experience, an integrated project has been organized to maximize all experience and technology shared within Korea's nuclear industry.

The KNGR design will meet the enhanced safety requirements and economic goals of future nuclear power plants in Korea, particularly with regard to investment protection and accident prevention. Construction is set to start in 1999, when 60% of the design will be completed.

IV. International Cooperation

Nuclear Overseas Business

Based on KEPCO's accumulated technology and international confidence built-up through its success in providing local electricity, KEPCO is now expanding its operation sphere to include the global community. Also, KEPCO is laying the foundation for global operations in the Asian region, where the demand for electricity will increase rapidly.

In December 1993, KEPCO signed its first international contract for engineering services for the maintenance of Guangdong nuclear power plant in China. In February, 1995, KEPCO signed a memorandum of understanding with China National Nuclear Corporation (CNNC) on the technical and economic joint study for the construction of nuclear power plants in China.

This year, KEPCO made an agreement with the Chinese government for

a joint study on the construction of Shandong Haiyang Nuclear Power Plants, and also provided Quinshan Nuclear Power Company (QNPC) with consulting services for the contract between QNPC and AECL for Quinshan Phase III project in China. Korea is stepping up its efforts to build a cooperative relationship with the Asian countries in the various fields for peaceful use of nuclear energy.

KEPCO also is pursuing cooperative joint ventures with advanced foreign suppliers such as ABB-CE in USA and AECL in Canada.

International Activities

By joining several Owners Groups set up by utilities operating and/or constructing the same type of reactors, KEPCO is continuously making efforts to improve plant safety and availability. KEPCO has been affiliated with international organizations such as the Institute of Nuclear Power Operations (INPO) and the World Association of Nuclear Operators (WANO), in order to exchange information on the nuclear field. KEPCO is also participating in various international cooperative activities for the promotion of nuclear energy development through the International Atomic Energy Agency and inter-governmental nuclear cooperation agreements.

In addition, KEPCO has made technical cooperation agreements with thirteen foreign utilities or nuclear organizations from eight countries to promote technological development, information exchanges, training, etc. Based on the agreements' frameworks, various cooperation activities are being executed, including periodic meetings and regular exchanges of information.

V. CANDU Status in Korea

As recognized, CANDU has earned the reputation as one of the world's most successful reactors since its first operation in Canada in the early 1970s. CANDU's combination of natural uranium, heavy water and on-power refueling is remarkable for its reliable power production.

Wolsong Unit 1 is the best performing nuclear unit in Korea on a lifetime basis and has been number one in the world annually three times. The CANDU units now under construction in Wolsong are

scheduled for completion in 1997, 98, and 99, and are increasingly localized with Wolsong Unit 4 reaching 75% local content. In 1999, KEPCO will have four CANDU units totaling 2,779 MWe bearing a considerable portion of KEPCO's nuclear capacity.

In addition, a feasibility study is being implemented to confirm the technical and economic viability of the CANDU 9 (900 MWe class). This study is to be completed before the establishment of the basic construction plan for two new nuclear units at Bonggil adjacent to the Wolsong site.

Last November, KEPCO and AECL signed a Memorandum of Agreement for CANDU Export to Third Countries, establishing a framework for future cooperation. Both parties will cooperate jointly in exploring third country markets for CANDU export and in participating in CANDU projects in such countries. Also, KEPCO is strengthening the inter-plant technical cooperation through an agreement with CANDU utilities such as Hydro-Quebec and New Brunswick Power Corporation.

VI. Conclusion

Nuclear power has contributed greatly to diversifying energy resources, lessening dependence on energy import, and improving environmental conservation in Korea.

There is no alternative but to continue on the chosen nuclear power path considering the current energy situation in Korea. KEPCO will make every endeavor in ensuring safer and more economic nuclear power plants through the technological development and international cooperation programs. Korean industries are now ready to contribute to our neighbors' nuclear power programs, with much experience accumulated over the last two decades.

JOHN D. SOMMERVILLE

1965	Graduated from Glasgow University with Honours Degree in Chemical Engineering.
1967	Emigrated to Canada and joined Ontario Hydro.
1967-75	Held various positions with Ontario Hydro. First attached to CRNL and then at NPD. Qualified as Nuclear Shift Supervisor.
1975-88	Moved to Point Lepreau G.S. with NB Power at beginning of construction program. Held the positions of Commissioning Superintendent (1975-77); Technical Manager (1977-87); Production Manager (1987-88), finally becoming Station Manager in 1988. In 1991, was appointed as Director of NB Power's Nuclear Program. During this later period with NB Power was one of the Directors of the CANDU Owners Group and Chairman of the CSA "N290" Nuclear Standards Committee.
1992-Present	Joined AECL taking up the position of Cernavoda Station Manager with AAC (AECL-ANSALDO Consortium).