KOREA ELECTRIC POWER CORPORATION (KEPCO)
TECHNOLOGY ASSESSMENT OF
FLUE GAS DESULFURIZATION FOR
COAL-FIRED POWER PLANTS

United States of America
December 9-22, 1993

Prepared for:

US - ASIA ENVIRONMENTAL PARTNERSHIP

WORLD ENVIRONMENT CENTER

DISCLAIMER

This project was sponsored by the U.S. Agency for International Development through WEC's Cooperative Agreement in support of the US - Asia Environmental Partnership (US-AEP). The opinions expressed herein are the professional opinions of the author and do not represent the official positior of the Government of the United States of America or the World Environment Center.

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I. EXECUTIVE SUMMARY

From December 9-22, 1993 an Environmental Business Exchange (EBE) was held for engineers of the Korea Electric Power Corporation (Kepco), the sole electricity-supplying company in Korea, to travel to the United States from Korea. On this exchange, two representatives from Kepco, Park Hun Kyung and Jo Young Dae, both serving in the position of Assistant Manager, Environmental Technology, visited three Flue Gas Desulfurization (FGD) vendors and four power generating stations employing the latest in U.S. Flue Gas Desulfurization technology.

Because of the fact that in Korea there is a lack of space for new power plants, most plants are built at the same location as existing ones. Therefore, it is common to have four to six plant units of large capacity located very near residential areas. In the past several years, residents have become very concerned about the environmental hazards associated with coal-fired power plants. In order to address environmental problems caused by coal firing, Kepco plans to install flue gas desulfurization (FGD) systems in the near future.

To this end, the participants of this exchange, took part in two weeks of site visits to observe FGD technology first-hand. The participants visited companies including: Electric Power Research Institute (EPRI), General Electric Environment Systems (GE-ES), Babcock and Wilcox, and Combustion Engineering. At each site visited, comprehensive presentations of FGD technology was given. Also, the exchange participants had the opportunity to speak directly with designers of FGD equipment and see it in use for application in their coal-fired plants.

The exchange participants received training in FGD technology at Radian Corporation from November 22, 1993 through April 2, 1994 independently of this EBE.

Funding for this project was provided through a Cooperative Agreement between the World Environment Center (WEC) and the United States-Asia Environmental Partnership (US-AEP).

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II. INTRODUCTION

To address the environmental problems caused by coal firing, Kepco plans to install FGD systems at power plants in Korea. At present, no FGD systems have not been installed in these plants, but, Kepco's goal is to have them installed in every plant by the year 2000. In order to learn more about available technology, representatives from Kepco, participated in an Environmental Business Exchange (EBE) to the United States. Exchange participants visited numerous sites to develop a clearer understanding of the type of equipment that is available. Kepco engineers participated in training sessions at Radian Corporation, independent of this EBE. The goal of the extended training was to become familiar with the various aspects of FGD system selection, design, operation, and troubleshooting. The engineers spent nearly ten weeks participating in training seminars given by Radian staff at their headquarters in Austin, Texas. Radian Corporation's engineers have also assisted them in the initial selection and specification process for a specific FGD application in Korea. Radian outlined the various parts of this process and provided intermittent review and assistance.

As a result of this exchange, the Kepco construction department is reviewing specifications for the first purchase of FGD systems and will solicit bids for purchase within a year. Kepco also entered into negotiations with Radian Corporation of the U.S. to receive training on FGD technologies that are currently being used in the United States.

The following report describes the activities, findings, conclusions, and recommendations of the Kepco engineers who traveled to the U.S. to gain an understanding of flue gas desulfurization technology as EBE participants during December 9-22, 1993.

III. DISCUSSION AND FINDINGS

A. INTRODUCTION

The Kepco Engineers began their exchange to the U.S. by visiting four power generating stations:

- Electric Power Research Institute (EPRI)
- General Electric Environmental Systems (GE-ES)
- Babcock and Wilcox (B&W)
- Combustion Engineering (ABB ES)

The purpose of these visits was to observe, FGD technology equipment and its effectiveness. The participants approached these visits with three research objectives in mind: (1) the improvement of existing control systems; (2) the development of retrofit options; and (3) the development of new processes.

B. SITE VISITS

1. EPRI High Sulfur Test Center - December 10

Location: Kintigh Generating Station of New York State Electric and Gas Corporation (NYSEG) on the shores of Lake Ontario, 45 miles northeast of Buffalo, New York.

Contact: Gary M. Andes, High Sulfur Test Center (HSTC) Facility Manager

Completed in 1984, following more than three years of construction, Kintigh Station generates about 688,000 kilowatts (KW) of electricity. This accounts for about 25 percent of NYSEG's total generating capacity, and helps guarantee their customers an adequate supply of electricity well into the 1990's. Kintigh Station uses about 1.5 million tons of bituminous coal a year, most of which comes from Pennsylvania and West Virginia. It also uses large amounts of crushed limestone in its sulfur removal systems.

2. General Electric Environmental Systems - December 13-14

Location: General Electric, Lebanon, Pennsylvania and the Harrison Power Plant/Allegheny Power System, Shinnston, West Virginia

Contacts: David G. Olson, Vice President, Sales; Raymond R. Gansley, Sr. Process Engineer; and Mel Jameson, Site Manager

While at GE ES Headquarters, the participants reviewed the company's Major Product Line Summary of Technology, and its FGD process. Afterward, the participants traveled to the Harrison Power Plant. The scrubbers at Harrison [the largest Allegheny Power System generating station (640 megawatts (MW) x 3)], are capable of removing at least 98% of the sulfur dioxide released from the coal burned. They will also preserve the jobs of 2,200 local coal miners and 5,500 mining support jobs that would have been threatened by switching to a low-sulfur coal mined elsewhere.

The plant's FGD system is currently under construction. When completed it will include:

- Absorber Modules (3)
  - Removes 98% of SO_2 Emissions
  - 110 feet high x 64 feet diameter
  - 12 absorber recirculation pumps (4/absorber)
- Scrubber Chimney
  - Absorber No. 2 built inside chimney shell
  - 1000 feet high x 124 feet diameter at the base
- Capital Cost of Scrubber System
  - More than $700 million
  - Nearly twice as much as the original station

3. Babcock and Wilcox (B&W) Environmental Systems - December 16-17

Location: Research and Development Division (R&DD), Alliance, Ohio and the Zimmer Generating Station [Cincinnati Gas & Electric Co. (CG&E)], Zimmer Station, Ohio.

Contacts: John M. Rackly, Vice President; Bob Telesz, Marketing Manager; James

J. Warchol, Manager, Chemical Engineering Station; Gregory T. Bielawski, Manager, Engineering; George S. Farthing, Supervisor, Clean Coal Projects Group; Edward Pyun, Manager, Off-shore Sublet Project; and Bob Clark, Supervisor, FGD System, CG&E

During their visit to B&W's Research and Development Division, the participants had the opportunity to review the company's:

- R&DD Overview
- B&W FGD
- Clean Coal Technologies
- Future Activities - Emission Control
- ARC Facilities (Tour)

A visit to the Zimmer Generating Station was also conducted. In 1982, for safety-related reasons, the Nuclear Regulatory Commission halted construction of the 97% complete Zimmer, which at the time was to be an 800 MW nuclear facility. On August 1, 1984, the owners announced their decision to convert Zimmer to a 1300 MW coal-fired installation, the largest coal-fired unit built worldwide. It officially began its service life on March 30, 1991.

CG&E's FGD system is comprised of:

- Magnesium-enhanced lime-based FGD system
- Six Scrubber Modules, semicircle around the stack (5 modules in operation, 1 module stand-by)

4. Asia Brown Boveri (ABB) Environmental Systems - December 20-21

Location: Birmingham, Alabama and the Curtis H. Stanton Energy Center [Orlando Utilities Commission (OUC)], Orlando, Florida

Contacts: Pramodh Nijhawan, Vice Pres., Business Development, International; Mick Chambers, Proposal Manager; Mark A. Walters, Product Manager, Wet FGD; Jonas S. Klingspor, Director, Technology Development; and Samuel J. Griffin, Mechanical Engineer, OUC

Topics reviewed included:

- ABB Wet FGD
- R&DD and Product Development

On their tour of the Curtis H. Stanton Energy Center in Orlando, the Kepco

engineers observed that the station has a generation capacity of 425 MW net for each of 2 units, one of which is still under construction. When construction is complete, the coal will arrive from Kentucky five times a week via 90-car trains.

The FGD system is designed so that flue gas from the Electro-Static Precipitator (ESP), which is essentially free of all fly ash particles, enters the limestone scrubber. The FGD system consists of 3 scrubber modules, but only 2 modules are in operation.

C. SITE VISIT FINDINGS

All of the facilities visited provided the Kepco engineers with documents and brochures of their technologies and introduced their technologies with visual presentations. The company engineers, especially those at B&W R&DD, introduced various technologies already in use for air pollution control.

The standard FGD absorber module manufactured by these facilities is a counter-current design. The slurry is sprayed downward from a series of headers and nozzles and scrubs the flue gas as it moves upward through the tower. The resulting product is formed in the recirculation tank in the bottom of the tower. Continuous pH monitoring is used to control the addition of fresh reagent. Density is also monitored continuously to control the blowdown of reacted solids. Level is monitored to control the addition of make-up water to compensate for evaporative losses.

Since positive control can be exercised on liquid distribution through good hydraulic design, the key to achieving intimate gas liquid contact is through uniform liquid distribution. Each spray stage must have a sufficient number of nozzles to cover the entire cross-section of the spray tower in a highly overlapping manner. In the GE ES and ABB ES design, this type of liquid distribution is used to design wet FGD systems.

In the B&W wet FGD System, the gas rises through a B&W-patented gas distribution tray, contacting a froth of slurry. The uniform flow of flue gas across the tower results in efficient contact of gas and reagent through the multi-level spray zone.

FGD systems installed in the U.S. have typically relied on multiple absorber towers. But the advanced single tower design provides high reliability and 100% capacity. This allows the owners to achieve SO_2 reduction efficiencies well in excess of 90% at significantly lower capital costs.

The In-Situ Forced Oxidation (IFO) system was developed to produce gypsum by-

product efficiently and reliably in limestone systems. In this process, both SO_2 absorption and oxidation steps are carried out int he same vessel -- replacing the separate oxidation vessel needed for External Forced Oxidation (EFO). At present, most FGD by-product in the U.S. is disposed in landfills. But, in Korea, Gypsum will be produced for use as a salable by-product because of the lack of disposal area.

D. FGD TECHNOLOGY TRAINING

In order to address the environmental problems caused by coal firing, Kepco plans to install FGD systems. At present, no FGD systems have been installed in these plants; however, Kepco's goal is to have them installed in every plant Kepco operates by the year 2000. The Kepco Construction Department is now reviewing specifications for the first purchase of FGD systems and will solicit bids for this purchase in within a year. Kepco entered into negotiations with Radian Corporation of the U.S. to receive training on FGD technologies that are currently being used in the United States.

The Korean Government has stated that Kepco must have a major role in future FGD systems. Kepco's Construction Department will procure FGD systems for units built between now and 1999. After 1999, Kepco plans to engineer, design, fabricate, and install its own FGD systems. In the next five years, the Kepco Research Center will be trying to gain all the knowledge it can on FGD systems.

Kepco has signed a ten-year term Collaborative Agreement for Flue Gas Desulfurization Technology in 1988 with Radian Corporation. Under this Agreement, Radian provides technology transfer to Kepco personnel in the areas relating to the engineering and process chemistry aspects of FGD technology for application at its coal-fired power plants throughout Korea. In exchange, Kepco will contract with Radian to assist them in FGD projects.

Thus, Kepco engineers were interested in attending the training offered by Radian Corporation. The goal of this training was to become familiar with the various aspects of FGD system selection, design, operation, and troubleshooting. The engineers have spent nearly ten weeks participating in training seminars given by Radian staff at their headquarters in Austin, Texas. Radian Corporation's engineers have also assisted them in the initial selection and specification process for a specific FGD application in Korea. Radian outlined the various parts of this process and provided intermittent review and assistance.

IV. CONCLUSIONS AND RECOMMENDATIONS

Messrs. Park and Jo were grateful to participate in a full itinerary exploring FSD technology. Facility visits provided the opportunity to observe the FSD technology in operation, and to discuss benefits with facility personnel and manufacturers. The participants will continue to identify suitable FSD equipment for Korea's power plants.

The participants expressed an opinion that a full-time consulting engineers would have complmented their facility visits, and that longer durations at each facility would have been preferable.

APPENDIX A

ITINERARY

ITINERARY

Date	Facility Visited	Location
Thursday, Dec.9	Fly from Austin to Buffalo	
Friday, Dec. 10	EPRI - High Sulfur Test Center	Kintigh (Buffalo), New York
Saturday, Dec. 11 Sunday, Dec. 12	Weekend in Philadelphia	
Monday, Dec. 13	General Electric ES	Lebanon (Harrisburg), Pennsylvania
Tuesday, Dec. 14	Harrison Generating Station	Shinnston, West Virginia
Wednesday, Dec. 15	Fly from Pittsburgh, PA to Akron/Canton, Ohio	
Thursday, Dec. 16	Babcock & Wilcox Co.	Arberton (Akron/Canton), Ohio
Friday, Dec. 17	Zimmer Generating System	Zimmer (Cincinnati), Ohio
Saturday, Dec. 18	Fly from Cincinnati, Ohio to Birmingham, Alabama	
Sunday, Dec. 19	Weekend in Birmingham	
Monday, Dec. 20	ABB ES	Birmingham, Alabama
Tuesday, Dec. 21	Curtis H. Stanton Energy Center	Orlando, Florida
Wednesday, Dec. 22	Fly from Orlando to Austin	

APPENDIX B

PERSONS AND ORGANIZATIONS VISITED

PERSONS AND ORGANIZATIONS VISITED

Name	Affiliation	Title
Swarupa Ganguli	WEC	Deputy Project Manager
Charles Hong	WEC	Deputy Project Manager
Gary M. Andes	EPRI	HSTC Facility Manager
David G. Olson	GE ES	Vice President, Sales
Raymond R. Gansley	GE ES	Sr. Process Engineer
Mel Jameson	GE ES	Site Manager
John M. Rackley	B&W R&DD	Vice President
Bob Telesz	B&W	Marketing Manager
James J. Warchol	B&W R&DD	Manager, Chemical Engineering Section
Gregory T. Bielawski	B&W R&DD	Manager, Engineering
George S. Farthing	B&W R&DD	Supervisor, Clean Coal Project Group
Edward Puyn	B&W	Manager, Off-shore Sublet Project
Bob Clark	Zimmer Generating Station	Supervisor, FGD System
Pramodh Nijhawan	ABB ES	Vice President, Business Development, International
Mick Chambers	ABB ES	Proposal Manager
Mark A. Walters	ABB ES	Product Manager, Wet FGD
Jonas S. Klingspor	ABB ES	Director, Technology Development
Samuel J. Griffin	Curtis & Stanton Energy Center	Mechanical Engineer, Orlando Utilities Commission

APPENDIX C

BUSINESS CARDS OF PERSONS CONTACTED

C. Business Cards of Persons Contacted

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Samuel J. Griffin
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Fax No. (407) 244-8794

APPENDIX D

LIST OF DOCUMENTS RECEIVED

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- WEC (Brochure)
- EPRI High-Sulfur Test Center (Brochure)
- Kintigh Generating Station (Brochure)
- Cleaning the Air (Brochure, GE ES)
- Design and Operation of Single Train Spray Tower FGD Systems (A. Saleem, GE ES, Dec., 1991)
- Ammonia Scrubbing of SO_2 Comes of Age with In-Situ Forced Oxidation (A. Saleem, GE ES, August 24, 1993)
- Allegheny Power System (Brochure, Energy for a Cleaner Environment)
- B&W R&DD (Brochure)
- B&W Brochure Binder
- Steam Book (40th Edition, B&W, 1992)
- B&W Air Pollution Control Technologies (Brochure)
- ABB in Power Generation & Delivery (Brochure)
- ABB FGD System (Brochure)
- Annual Report 1992 (ABB)
- Curtis & Stanton Energy Center (Brochure)

APPENDIX E

CURRICULUM VITAE

CURRICULUM VITAE

Jo/Young Dae

-
- Nationality: Republic of Korea
- Affiliation: Korea Electric Power Corporation
- Title: Environmental Technology Section, Assistant Manager
- Academic Career: Chonbuk University, Chemical Engineering Department

Park/Hun Kyung

-
- Nationality: Republic of Korea
- Affiliation: Korea Electric Power Corporation
- Title: Sochon Thermal Power Plant, Operating Engineer
- Academic Career: Chonbuk University, Mechanical Engineering Department

APPENDIX F

PHOTOGRAPHS

F. Photographs

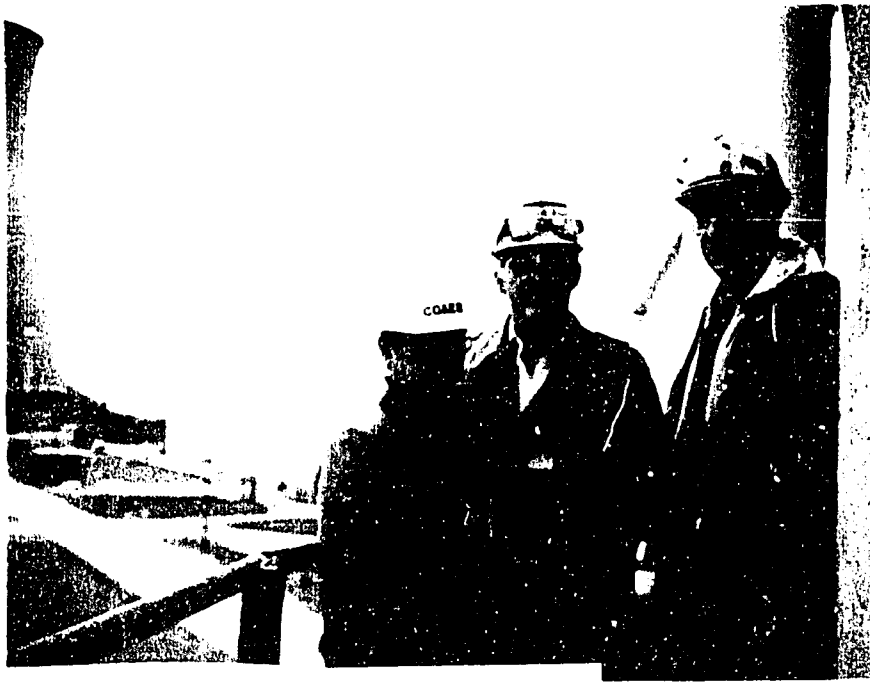
1. Pictured at the General Electric facility, from left to right: Mr. Park (Kepco), David Olson (GE), Mr. Jo (Kepco), and Swarupa Ganguli (WEC).

2. From left: Swarupa Ganguli, Mr. Olson and Mr. Park.

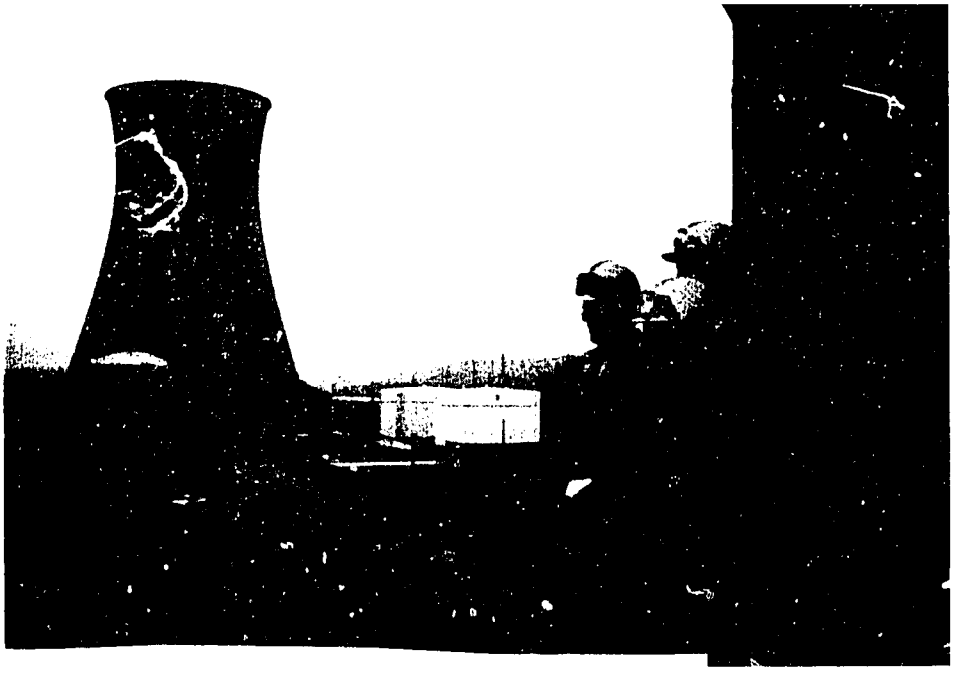
F. **Photographs (Continued)**

3. Mr. Jo visits a Babcock and Wilcox (B&W) facility.

4. Mr. Park listens to B&W engineers discuss FGD technology.



5. Mr. Jo with ABB engineers on site.



Mr. Park viewing ABB facility with engineers.

F. **Photographs (Continued)**

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WEC/US-AEP

Environmental Business Exchange (EBE) Trip Reports

Febuary 22, 1995

Trip Reports as per Cooperative Agreement (CA) AEP-0015-A-00-2055-00 in Support of the U.S.-Asia Environmental Partnership

EBE ID#	EBE DATES	TITLE OF TRIP REPORT
INDI-1I	11/7-23/93	Oil Absorbent Demonstration
INDI-1K	12/6-29/93	Review of Incinerator Operations, Indian Thermal and Cyno Clean
INDI-2	4/23 - 5/6/94	Review of Pollution Prevention Control Technology in the Textile Industry
INDI-5	4/30 - 5/10/94	Clean Coal Technology Evaluation
INDI-1P (1&2)	5/94-8/94	Clean Technology for Paper Mills - Esvin - Parts 1&2
INDI-1R	6/18-30/94	Evaluation of Biological Formulations for Industrial Wastestreams Treatment (Premier Ziba)
INDI-1Q	6/18-7/1/94	Indian Boilers Manufacturers' Association Trade Mission
PHIL-8	9/27-10/6/94	Technical Assistance on H2S Gas Abatement Systems (PNOC)
HONG-1	10/23-11/9/94	Coleman Energy and Environmental Systems Technology Transfer
KORE-1	12/9-22/93	Fuel Gas Desulfurization Technology Assessment (KEPCO)
INDI-1L	1/17-2/23/94	Corporate Environmental Mission (IT Corporation Exchange)
INDI-4	3/11-30/94	Evaluation of CS_2 Recovery in Rayon Mills