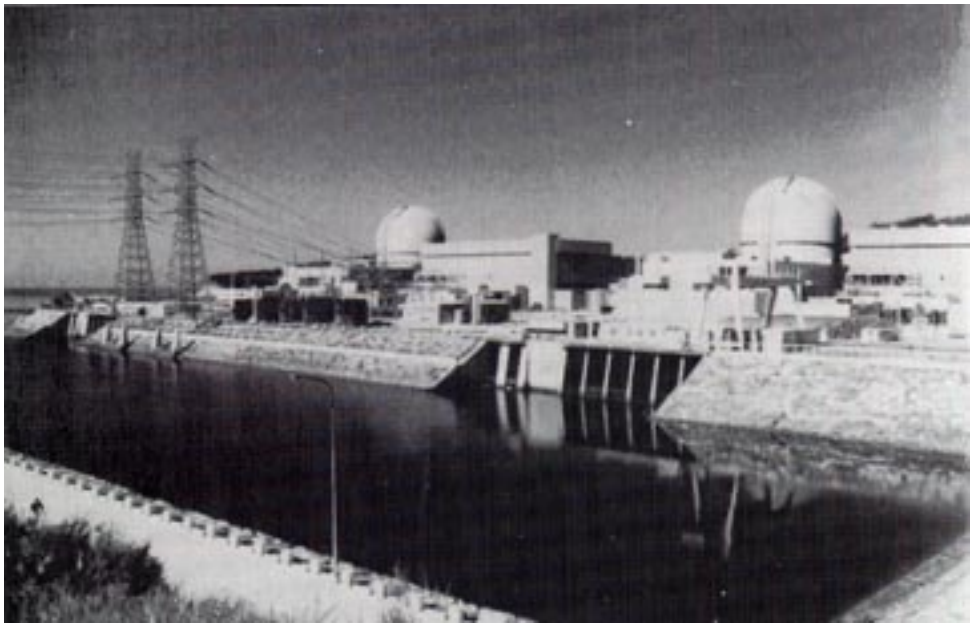

Left: Initial problems surfaced at the Yangwang PWR units in the feedwater-regulator valves.

In retrospect

A secure electricity system is vital to Korea's growing economy but despite a continuing generating program, supply barely keeps ahead of demand. When unscheduled power outages in five of KEPCO's pressurized water reactors kept recurring a permanent solution had to be found - and fast

Korea Electric Power Corporation (KEPCO) is the Sole company responsible for the generation of all electric power in Korea. Formed as a public corporation in 1982, the company is the result of an unbroken line of previous corporate mergers that began as the Seoul Electric Company, in 1898.

As part of its corporate mandate, KEPCO is committed to developing and supplying a stable source of electricity for the people of Korea. To fulfill this obligation, the company has a number of generating facilities. These range from hydro-power plants to nuclear, fossil and LNG fuelled facilities. Nuclear power is emerging to play a leading role in today's Korea. In 1991, nuclear-generated power accounted for 47.4 per cent of the country's total - producing 56,311GWh.

Currently, nine nuclear power plants are in operation and seven additional units are under construction. The nuclear power plants are located at four different sites on the southern end of the Korea Peninsula and use sea water for their cooling systems. The Kori, Wolsong and Ulchin plants are located on the eastern coast and Yonggwang site is on the western coast.

Korea's growing economic base places continuous strain on its existing power resources since supply keeps barely ahead of demand. In this environment, any disruption in the generation of power can be critical to the reliability and the country's economy. Consequently, when concerns were raised over unscheduled power outages in five of the company's pressurized water reactors (PWR), KEPCO's Nuclear Power Generation Department charged itself with finding a permanent solution to preventing such outages.

Unsuccessful attempts

The problem of unscheduled power outages initially surfaced at the Kori location, units 2, 3 and 4 and at Yonggwang, units 1 and 2. "We were having problems from the beginning with our feedwater-regulator valves in the PWRs specifically the Kori and Yonggwang units," said Kyoung Sik Jang, manager of the mechanical and electrical department of Nuclear Power Generation. "We were experiencing stem Breakage, extreme vibration and poor flow control with the feedwater-regulator valves, which resulted in scramming, or shutting down, the plant.

"In an attempt to solve the problem, the first thing we did was to weld the valves' plugs and stems together," said Jang. "While this alleviated the stem breakage we still had significant vibration within the valves and poor process control. The vibration was causing the valves to wear in a relatively short period of time, driving up our operations and maintenance (O&M) costs. Also, inadequate fluid control within the valve made it difficult to maintain the proper steam-generator level, which in turn created control problems downstream of this system."

Unanticipated disintegration

In researching the problem with the original valve manufacturer and the supplier of the core system, it was determined that the energy in the fluid flowing through the valves was not dissipating correctly, causing vibration modes in the plug. It was felt that this vibration was causing the stems to break. KEPCO was advised to put a quadrant-flow baffle plate downstream of the valve or in the seat of the valve.

"At the suggestion of the valve manufacturer, we installed the baffle plate in the trim of the valves," explained Jang. "As the flow rates through the valves were as high as 4.9 x 106 lbs/hr (2.2 x 106 Kg/Hr), and the inlet pressure equaled l3l3psia (9 MPa), we expected the plate to isolate a major portion of the plug from the throttled flow stream. By dividing the flow from one single stage into four equivalent stages, and reducing the total energy of the fluid, we anticipated a reduction in stem oscillation, an overall reduction in line shake and elimination of excessive stem loads."

Although the baffle plates contributed to improving the vibration problem, the plates were subject to severe wear and erosion. In fact, when KEPCO opened up the valves several months later, the baffle plates were no longer there. The baffle plates had completely disintegrated and had to be retrieved, in pieces, from the feedwater and steam generator piping downstream.

When the pieces were returned to the system supplier KEPCO were told that since a carbon-steel material was used for the baffle, the whip of the quadrant flow over time caused the plates to erode until they gave way. It was suggested that a stainless steel material should be used to reduce erosion but every cycle the material loss on the webs would need to be measured and replacement plates installed if necessary.

Searching for a solution

KEPCO did not consider the installation of baffle plates as a permanent answer as

Plant	Unit	Reactor Type	Capacity (MW)	Commercial Operation	Status
Kori	1	PWR	587	78.4	Operational
	2	PWR	650	83.7	Operational
	3	PWR	950	85.9	Operational
	4	PWR	950	86.4	Operational
Wolsong	1	PHWR	678.7	83.4	Operational
	2	PHWR	700	97.6	Under Construction
	3	PHWR	700	98.6	Under Construction
	4	PHWR	700	99.6	Under Construction
Yongwang	1	PWR	950	86.8	Operational
	2	PWR	950	87.6	Operational
	3	PWR	1000	95.3	Under Construction
	4	PWR	1000	96.3	Under Construction
Ulchin	1	PWR	950	88.9	Operational
	2	PWR	950	89.9	Operational
	3	PWR	1000	98.6	Under Construction
	4	PWR	1000	99.6	Under Construction

Left: Nuclear operation and construction status. Information taken from KEPCO's 1992 Annual review

Above; DRAG control valves from Control Components Inc. Use a unique disk stack trim design for severe service applications.

the plates needed to be inspected at every outage, replaced periodically and additionally if pieces broke off inside the system they could harm the downstream components posing an unnecessary risk to the system.

"The valves were costing us millions of dollars in lost revenues as a result of plant shutdowns. The O&M costs were also prohibitive. We wanted to find a permanent solution to the vibration and control problems that would provide continuous and reliable flow control while withstanding the high fluid velocities within the system," said Jang.

Dissatisfied with the attempts of the original valve manufacturer to solve the problems, it was decided to open the options and solicit solutions from outside vendors. In May 1990, KEPCO sent out an invitation to bid to valve suppliers giving technical requirements and including additional contractual delivery and performance constraints.

KEPCO eventually chose to go with a retrofit solution supplied by Control Components Inc (CCI) of Rancho Santa Margarita, California.

Primary reasons for KEPCO's choice was CCI's extensive experience with retrofitting other manufacturers' valves with its DRAG trim in situations where improper fluid control in the valve adversely affected the downstream system. In most of these cases, excessive vibration and noise within the control valves were caused either by high fluid velocities through the valve, flow cavitation or both retrofitting the existing valves with a DRAG type trim results in the elimination of vibration and improved flow control. Based on CCI's experience with similar situations, KEPCO felt confident that such a retrofit solution would also solve their problems.

Trimming technology

"When we reviewed the problems and investigated the causes, we determined that the most cost-effective solution would be to retrofit the existing feedwater-regulator valves with our patented DRAG trim," said David Minoofar, international sales manager for CCI. "Valve retrofits provide the benefit of DRAG technology without the costly burden of valve replacement. Retrofitting the valves would also enable us to meet KEPCO's tight delivery schedule."

CCI's DRAG trim technology is custom-designed for each application. It employs a unique stacked-disk trim design, with each disk etched on one side with a series of right-angle turns. This provides a multiple-stage, pressure-reducing flow through the valve body, by forcing process fluids to follow a tortuous path through the trim. The resistance provided by these turns controls the velocity of the fluid at safe levels, regardless of the pressure drop. Problems such as noise, erosion from cavitation and vibration are therefore eliminated.

Once CCI was appointed as the supplier, their field engineers were sent in and measured the existing valves, ordered materials and began manufacture of the valves before the contracts were signed to ensure the severe scheduled delivery date was met. Despite CCI's confidence, contingency designs were drawn up in case different

Left: KEPCO's Wolsung nuclear plant located on the eastern coast of Korea

and unknown conditions and tolerances were encountered.

Retrofit fulfillment

The new valve retrofits were installed between 25 May and 6 June 1991 with the units brought on-line 9 June 1991.

"Since the retrofits were installed, we have not experienced any unscheduled outages that have occurred as a result of valve failures," said Jang. "The units are operating at capacity and there is no vibration in the valves or the piping system. This has resulted in our maintenance costs decreasing as well. We no longer have to go in to inspect the valves at each outage. In today's economy, where O&M costs are heavily scrutinised, this represents significant savings to the plant.

"We are also experiencing quicker start-up times resulting from improved fluid control," continued Jang. "This is improving conditions in the downstream systems and contributed to making the system more reliable."

KEPCO's Kori unit 2 has exhibited exceptional performance since the retrofit. Since 1991, the Kori unit 2 has a marked capacity factor of 99.4 per cent, achieving the first rank among 202 operating PWR units in the world. This unit has also accomplished 387 days of continuous operation before shutdown for refuelling.

As a result of the excellent performance of the Kori and Yonggwang plant retrofits, all of the feedwater-regulator valves in the other PWR units have been retrofitted with the new DRAG technology. Although stem breakage was not experienced in the other plant's valves, on closer inspection it was realized that the same hunting and vibration problems were evident. Extra time was also being wasted during start-up due to poor control problems.

Now the DRAG-retrofitted feedwater-regulator valves perform within the specified tolerances to ensuring a stable and reliable power supply for Korea. Left: KEPCO's Wolsung nuclear plant located on the eastern coast of Korea.

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