The Evaluation of Radiation to Zinc Injection of Pressurized Water Reactor(PWR)

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1. Introduction

Recently, due to the increase in the number of years of operation and the extension of the life span of NPPs in Korea, accumulation of radioactive corrosion products in the primary system has caused the increase of radiation exposure of workers during the O/H (Overhaul).

In the case of overseas, it has started in the mid-1990s with US Farley 2, as of October 2011 a slight amount of zinc (5 to 40 ppb) was injected into RCS from 76 PWRs (PWR 29%)[Fig. 1]. Consequently, the radioactive corrosion products (Ni, Fe, Co, etc.) existing in the corroded oxide film of the primary system were stabilized by displacement reaction, so the corrosion was delayed and radiation exposure was reduced.

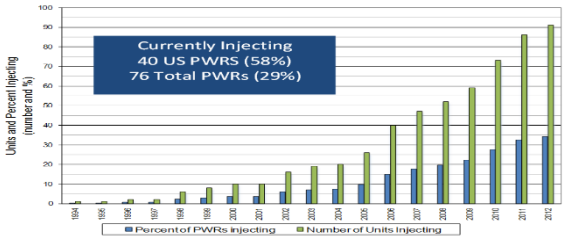

Fig. 1. Foreign PWR reactor coolant zinc injection status.

In the initial stage after the zinc injection, the increase in the amount of corrosion products affects the loads of treating waste water in RCS.

However, the results of applying continuous zinc injection and dense mesh filter, we could see the reduction of radiation dose more than 30% before & after injection at the points of loop piping and channel heads of SG (steam generator) in Hanul unit #1.

In this paper, we study the effects of zinc injection on the management of radiation safety and what should be considered for better management of radiation safety.

2. Main Subject

2.1 The formation process of radioactive products

The main cause of the formation of the radioactive product is that corrosion oxide on the internal surface is moved to the core in the primary coolant. So, it is activated and the radioactive corrosion oxide is left from the core and re-deposited on the pipe surface in the system.

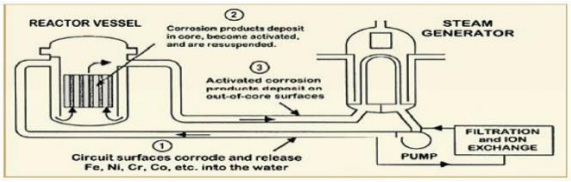

Fig. 2. Formation process of radioactive product.

In addition, the oxide film formed in the RCS is divided into inner and outer part. Firstly, the inner oxide film exists as a general spinel compound in the form of chromite. It is relatively stable in the coolant water. Secondly, the external oxide film is formed to outward. It is located at the outermost part of the oxide film of the system and directly contact with the reactor coolant.

Table 1. Composition of Corrosion oxide

	deposited oxide			grown on oxide			
Oxide / Cation	Fe_3O_4 (Magnetite)	Fe_2NiO_4 (Nikel Ferrite)	NiO (Nikel Oxide)	$Fe_{3-x-y}Ni_xCr_yO_4$ (Mixed Ferrite Chromite)	$FeCr_2O_4$ (Iron Chromite)	$NiCr_2O_4$ (Nickel Chromite)	Cr_2O_3 (Chromia)
Fe^{2+}	33.6	0	0	(1-x)/3×100	33.3	0	0
Fe^{3+}	66.6	66.6	0	(1-y)/3×100	0	0	0
Ni^{2+}	0	33.3	100	x/3×100	0	33.3	0
Cr^{3+}	0		0	y/3×100	66.6	66.6	100

2.2 Analysis of change of dose rate before & after zinc Injection

Zinc was continuously injected in the form of zinc acetate aqueous solution in RCS (concentration: 5 ppb, average : 14 g/day) and the location of injection is at the pipe between the charging pump and VCT of the CVCS system.

Table 2. Zinc (Zn) injection amount per cycle

operating cycle	Zinc injection cycle	Period of operation	Period of Zinc injection	Average concentration of Zinc injection	Total amount of Zinc
17cycle	1cycle	'09.03 ~ '10.08	'10.04~'10.08 (129days)	5.6 ppb	1.8 kg

Standardized and stable dose measurement is required to evaluate dose rate of the system before & after zinc injection. So, in order to reduce the measurement error and obtain a stable dose rate, standardized method should be considered for the location of measuring dose rate, the time of measurement and equipment of measurement. For method of standardized dose measurement, SRMP (Standard Radiation Monitoring Program, TR-1015119_ Nov.2007) was applied. The SRMP proposed by EPRI is standardized method to measure dose rate for each type of NPPs.

In order to obtain the dose rate of the same condition for each cycle, firstly, the time of measuring the dose rate at the loop piping was immediately after the end of the oxidation ditch (OD) process during OH (Overhaul) satisfying the drainage condition. Secondly, the time of measuring the dose rate at the channel head of the SG (steam generator) was immediately after opening the SG 'Man-way' (just before nozzle dam installation) within three weeks after plant shutdown. In addition, measuring points of dose rate were located in loop Piping (15 measuring points) and channel heads of SG (36 measuring points) in RCS.

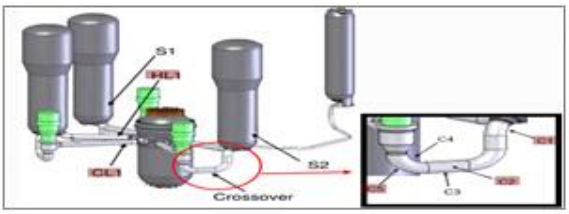

Fig. 3. The points of dose rate measurement at reactor coolant Loop Piping.

In conclusion, points of dose rate were reduced by 31.7% after one cycle zinc injection and the phenomenon of dose reduction occurred overall in the system. This effect was confirmed by the fact that zinc injection can reduce the dose rate without being restricted by the size, shape and physical accessibility of the system respectively.

Table 3. Comparison of dose rate before and after zinc injection

Cycle	Total dose of RCS Loop piping	Total dose of SG water box	Average reduction rate
OH 116 (before Zinc injection)	9.40 mSv/hr	1101.00 mSv/hr	31.7%
OH 117 (after Zinc injection)	6.41 mSv/hr	752.20 mSv/hr	
Reduction amount(%)	2.99(31.8%)	348.8(31.6%)	

2.3 Effect and consideration on radiation safety management by injecting Zinc

As can be seen from the above results, the major consideration on management of radiation safety in reduction of dose rate after zinc injection is to reevaluate the dose rate of the workplace in RCS and to reduce the number of workers considering the reduction of the shielding volume during OH (Overhaul)

3. Conclusion

The zinc injection of the first NPP in Korea was carried out in Hanul unit #1 at the 17th cycle starting from april 2010. It was found that the effects of dose reduction through displacement reaction of Zinc injection in the corrosion products of RCS. It is considered to be highly applicable to future technologies of dose reduction and expected to contribute to management of dose exposure to workers and improvement in management of radiation safety.

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