Evolutions to Reduce Occupational Exposure During Outages in Korean NPPS

H.J. AHN, S.K. KIM Korea Hydro and Nuclear Power Co., Seoul, Republic of Korea

Introduction

The function of ALARA infrastructure in the KHNP(Korea Hydro and Nuclear Power) has been strengthened since the project of IAEA/RAS-22 was launched. During the last three years several good practices were introduced by the IAEA project and many of them were implemented or further developed into normal practice in Korea NPPs. Significant improvement in radiation work environment have achieved by the use of quick installation of flexible lead shields and a blower system in line with the S/G manhole. Among many good practices, the control of water level in RCS, which may have different practice in each country, and the elimination of the trapped gas inside Steam Generator will be discussed in-depth in this paper

Collective dose trend in YGN Unit 3&4

YGN(YongGwang NPP) unit 3&4 has been operated since it was constructed in 1995 and 1996 for each, which has a capacity of 1,000MWe per unit of 2 loops, PWR. Y3&4 has been achieved 6 times of one cycle trouble free operation including Y3-7th cycle on 2003 and 2 times of the highest unit capability factor on the world since commercial operation on 1996. According to the WANO performance indicators report on 2002, Y3&4 has 0.52 man-Sv/unit in the annual collective dose on 2002, which was far below the world average 0.78, and KHNP average 0.58. Annual collective dose on 2001 was recorded 0.55 man-Sv/unit on Y3&4, 0.83 on the world average, 0.70 on KHNP.

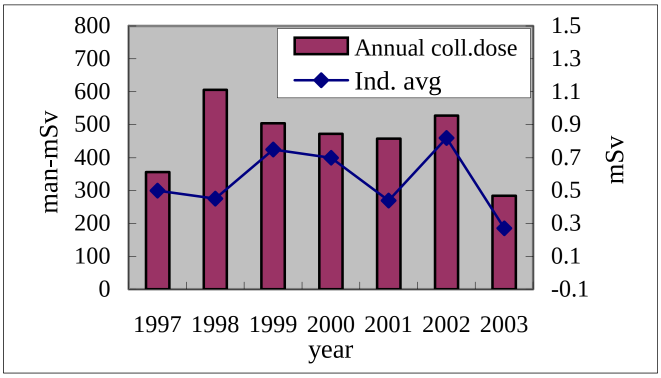

Fig. 1 Annual collective& Indivisual dose on YGN 3&4

Table 1. YongGwang NPP 2 Outages for year

	1997	1998	1999	2000	2001	2002	2003
Unit 3	2nd	3rd	4th	5th		6th	7th
Unit 4	2nd		3rd	4th	5th	6th	

Based on annual exposure history the annual collective dose was evaluated approximately 500 man-mSv if it was performed routine maintenance job with 1 unit outage. Robot has been used to plug and sleeve the tube of steam generator since Y4-5th in 2001. The dose reduction using the robot for tube plug accounts for 70 man-mSv approximately. The dose occurred during the steam generator maintenance was account for 35% on 2003, but approximately 40% on average of the past results. Fig.2 shows the collective dose trend of maintenance of the steam generator & refueling for each outage. This dose was largely dependant on radiation source, engineering tool, and worker's skill. As shown on the Fig.2 the collective dose for each work is tend to decrease, but the dose for steam generator plugging was risen peak at Y3-4TH and Y3-5TH and the all of dose was slightly increased at Y3-6TH. The reason was that tubes to be plugged or sleeved and all of this work was implemented by hands. This high dose was solved by utilizing the robot in the later which was performed a series of working process to plug & sleeve instead of worker's jumping into the steam generator chamber. The dose mounted at Y3-6TH was come from the increased radioactivity by tramp uranium in the reactor core that was loaded the long-term fuel since Y3-6TH outage. This was made out by the shut down chemistry and the gas purification at Y3-7TH.

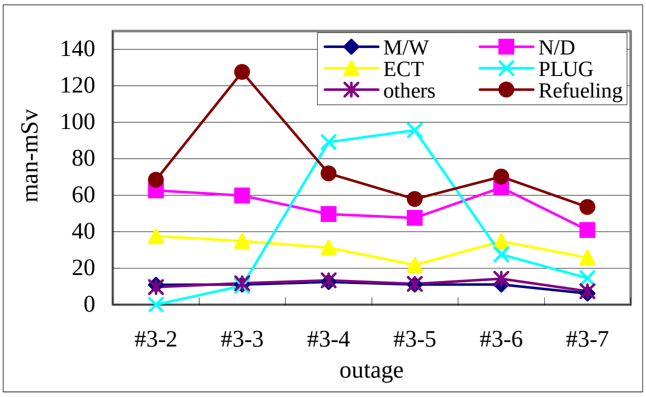

Fig. 2 Dose Trend for each outage

Engineering Techniques to reduce radiation sources

Considering RCS Level

From Y3-2TH ALARA, maintenance section raised the issue to fill up RCS water during the low cavity maintenance to cut down dose rate. Reactor coolant water was filled to 115' to alleviate the radiation from the reactor core during stud hole cleaning and other works in the reactor low cavity, which was cut down the environmental radiation of the cavity to 90 %. All of these were decided to adopt the process and engineering tools throughout the discussion on ALARA meeting.

Properly Humid air extraction system

Some of the problems were still pending without making out clearly due to changing the authentic design. The collective dose for the steam generator ECT (Eddy Current Test) was recorded high in the summer because ECT probes & heads are frequently stuck to the steam generator tube on the humid air. It was come from the design problem that containment building HVAC was lined up only one chiller system. It was delayed to complete the ECT during outage because ECT probes and heads were happened so many troubles due to stick into the steam generator tube. The workers were substantially exposed high radiation to fix these problems. It was identified as malfunction rising from much humidity. To ease the trouble the probe was substituted with durable material persisted in humidity. And it was also installed high volume fan to extract the humid air. After changing the material and installing the high volume fan, the troubles were considerably reduced. It was finally taken short the times to implement ECT and reduce the collective dose for ECT.

Mock-up training

Mock-up training was implemented 2 – 3 times for the high radiation works including jumping into the steam generator, the pressurizer to get accustomed. These technological behaviors guaranteed reliable and speedy works, consequently leads to decrease the collective dose. A variety of mock-up tools were prepared to mock-up training including the exact replica of the steam generator chamber for nozzle dam install, in-core instrument seal table for replacements, RCS boundary valve for lapping, pressurizer internal for heater removal, as shown on Fig. 3.

Fig. 3 Mock up training facilities

An evolutonal Technique for shutdown chemistry

Radionuclides dissolved in RCS were drawn back to the demineralizer by extracting the coolant from RCS to CVCS during operation. Especially it was critical step to remove the radionuclides by shut down chemistry facing the outage for the better radiological field condition. Iodine is mainly released to RCS through small defects in the fuel clad. In normal operation, iodine exits in the alkaline-reducing coolant as iodide ion. This is easily removed by anion exchanger of demineralizer operating in the borate form. During the initial stages of shutdown reducing conditions are maintained (acid-reducing conditions) but both the pH and temperature are reduced. During the acid–oxidizing phase, especially when excess hydrogen-peroxide is present, fission product iodine is mainly oxidized to the iodate ion, IO_3^-, particularly at low concentration which further radiolytic oxidation of I_2, HIO. This ion is less efficiently removed by the anion exchange resins. This would be especially reminded when iodine spiking occurred by fuel failure. Also the reactor vessel head is removed and refueling cavity is flooded with incomplete iodine removal leads to the continuing release of volatile molecular iodine(I_2) or hypoiodous acid(HIO). Under these circumstances the workers are vulnerable to inhale and expose to diffused radionuclides in the containment building. Table 2 show that the radioactivity in RCS was decreased during shut down chemistry. H_2O_2 was added after iodine was efficiently removed. The procedure states that after the concentration of iodine should be decreased to 0.01uCi/g hydrogen peroxide could be added.

Table 2. Radioactivity in the RCS during Y4-6TH shutdown chemistry

(unit : µ Ci/cc)

Date	Co-58	Co-60	I-131	T/A	REMARKS
10.13 11:06	2.601E-03			1.236E-01	Coast down, CVCS
10.14 00:05	6.013E-03			5.153E-02	RX. POWER 5%
05:35	6.341E-02	9.172E-04	2.814E-01	1.038E+00	
10.16 03:40	2.261E+00	1.144E-02	6.463E-05	2.701E+00	H_2O_2 Pouring
04:40	2.293E+00	1.149E-02	6.649E-05	2.700E+00	RCP1A,1B→2A, 2B exchange
05:10	2.253E+00	1.064E-02	9.689E-05	3.024E+00	CVCS 02F → 01F;dif. pr Hi
05:40	2.402E+00	1.030E-02		2.920E+00	
10:31	1.806E+00	8.945E-03	7.798E-05	2.205E+00	RCP 1A, 1B
10.17 01:46	5.820E-01	2.877E-03		7.286E-01	RCP 2A, 2B
18:05	1.763E-01	1.162E-03	6.495E-04	2.527E-01	RCP 1A,1B op.
22:20	1.340E-01	9.501E-04		2.097E-01	RCS pr : atm..
06:10	9.884E-02	5.705E-04	3.841E-04	1.491E-01	Charging p/p 1EA
10.21 10:54	6.230E-03	2.120E-04	1.398E-04	8.148E-03	

An evolutional discharge system to eliminate radioactive gases from the reactor coolant

The main causes of lower dose at Y3-7TH outage(last year) comes from the gas purification that gaseous radionuclides are extracted from the RCS by operating CVCS and temporary low volume recirculation directly before opening the steam generator man-way. The latter is carried out by extracting the gas in RCS through the PZR man-way and extracting line is connected to Low Volume Purge Recirculation System. Empty space of the steam generator and the pressurizer was filled with gaseous radionuclides after the RCS drain to mid-loop. Before opening the steam generator man-way, temporary hose and movable blower were connected pressurizer man-way to the low volume recirculation(Fig.4) and operated until the concentration of gas decreased below the limit of as follows.

I-131 : below the 0.01 μCi/cc
Xe-133 : below the 0.05 μCi/cc
Total Activity : below the 0.05 μCi/cc

As a result of purification there are lowered the dose rate and the concentration of radio-nuclide in S/G and containment air as shown on table 3. The improvement of radiological condition in RCA finally brought about the reduction of the number of internal exposure, the occupation exposure and speed up the outage milestone.

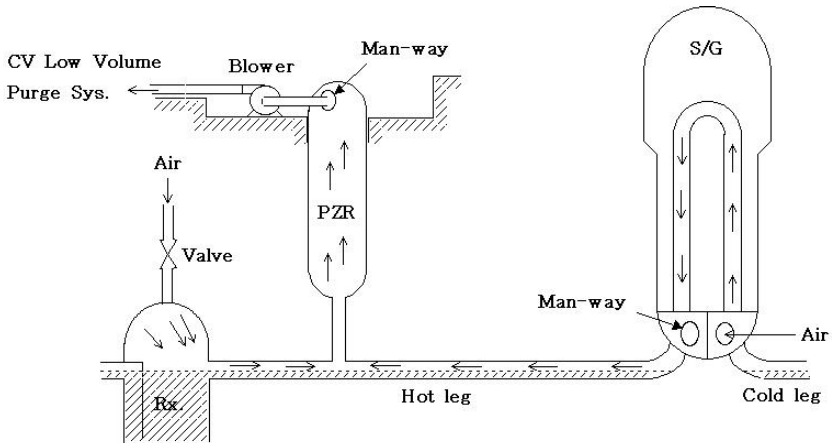

Fig. 4 Schematic diagram of iner-gas extraction system

Table 3. Containment air concentration around the S/G for each outage

(unit : Bq/cc)

	Y3-3		Y3-4		Y3-5		Y3-6		Y3-7	
	S/G 1	S/G 2	S/G 1	S/G 2	S/G 1	S/G 2	S/G 1	S/G 2	S/G 1	S/G 2
G	N/D	N/D	1.05E-01	5.07E-02	N/D	N/D	N/D	N/D	N/D	N/D
P	5.05E-05	4.21E-05	4.54E-05	3.11E-05	N/D	N/D	1.50E-06	1.35E-05	N/D	N/D
I	1.51E-06	N/D	N/D	N/D	N/D	N/D	N/D	2.48E-06	N/D	N/D

Evolutional temporary shielding techniques for the use of lead or water

Stainless shield containing 3 tons of water was provided to shield the high radiation at Y4-5TH , which was used to shield the radiation from the reactor upper guide support (UGS) in the reactor cavity during replacing the in-core instrument seal table next UGS and also used to protect the workers by shielding the radiation the reactor lower internal during lifting

It was made use of valuably to shield in various situations by extending with lead shield. Fig. 5 shows the lay out diagram that water shield was laid between UGS and in-core instrument seal table. It was decreased the work place radiation to 80 % after shielding. Before using this water container a lead brick was installed for high radiation shield, but it was required to prepare more efficient shield in the Y3-4TH ALARA.

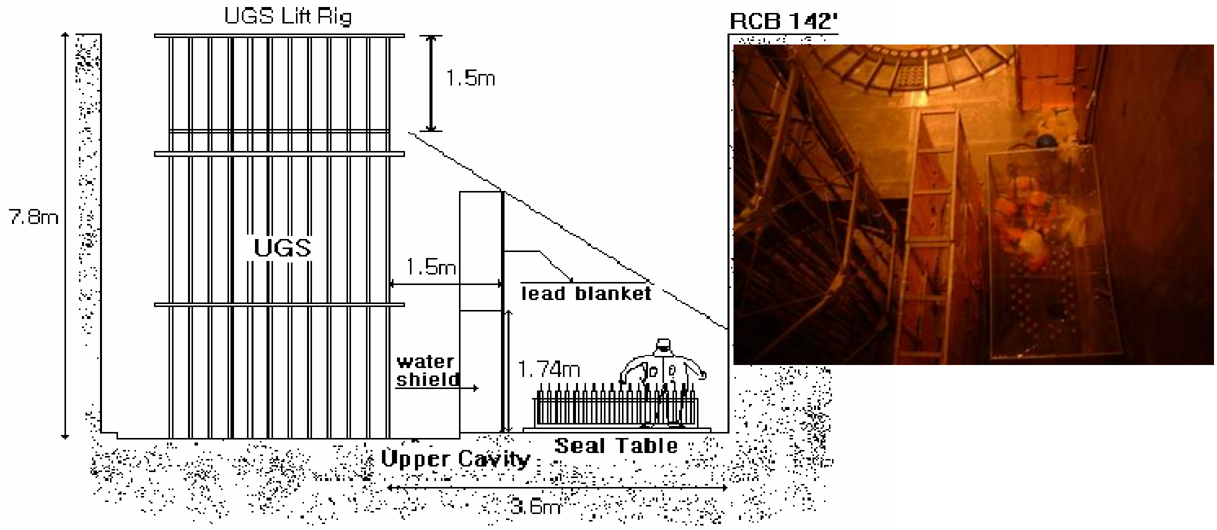

Fig. 5 Lay out Diagram for water shields