APR-1400 Gaseous Waste Management System Optimization for Dose Reduction of Krypton, Xenon, and Iodine Radionuclides

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1. Introduction

The use of nuclear power has grown over the years as a stable and reliable baseload power. South Korea has an increasing fleet of NPP. Within recent years, the industry has improved waste management systems in the NPP, to decrease exposure to the environment. The reference plant is the Shin Kori 3&4, APR-1400, located at the Kori complex. This complex is located within a 25 km radius of two large cities, Busan and Ulsan, with a population of 3.5 million and 1.1 million respectively, thus making dose reduction an important area of study. The APR-1400 waste management system minimizes off-site exposure to these neighboring communities and the environment. The fission products of interest in this study are Kr, Xe, and I, which originate from fuel and tramp uranium on fuel surfaces. The purpose of this study is to optimize the existing APR-1400 Gaseous Waste Management System (GWMS) to further minimize dose.

2. Gaseous Waste Management System

The GWMS comprises of the gaseous radioactive waste subsystem (GRS) and the building ventilation subsystem (BVS).

2.1 Gaseous Radioactive Waste System

The GRS employs charcoal delay beds which adsorb Kr, Xe, and I until they decay to acceptable environmental release levels set by the regulator [1].

2.2 Building Ventilation System

The BVS vent points are shown in Fig. 1-A while the ventilation points identified for improvements are outlined in Fig. 1-B, which also shows how the GRS forms part of the whole system. The ventilation system is designed to control gaseous effluent release to meet regulatory criteria, see section 3.2.

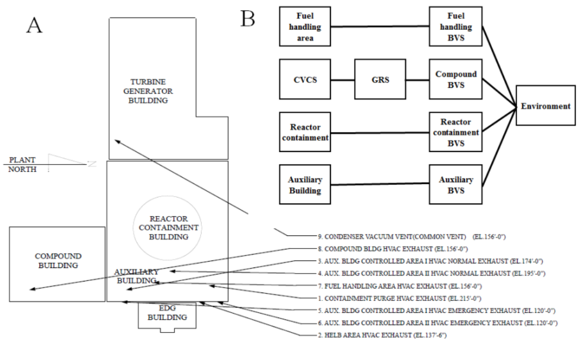

Fig. 1. A: APR 1400 BVS, B: Identified Ventilation points for Optimization [1].

3. Optimization

3.1 GRS

Alternative GRS waste treatment techniques were studied and are summarized in Table 1.

Table 1. GRS treatment techniques [2]

Treatment Method	Features	Limitations	Secondary Waste
Sorption	Removal of inorganic & organic iodine	Humidity control is required	Spent sorption media
	Sorption media chemically impregnated with charcoal or zeolites	Limited operating temperature-charcoal	
		High cost of impregnated media	
Cryogenic trapping	Isolate Kr-85 from off-gases by sorption on solid sorbent	Further reprocessing and packaging for long term storage is required	Spent sorption media
	Operate at high pressure & low temperature	Commercial experience is limited	
	Sorbent reused multiple times after Kr is recovered		
Delay decay	For decay of short lived noble gases	Large beds are required to provide for long retention times	None
Wet scrubbing	contact of target compounds or particulate matters with the scrubbing solution	Not practical for high volume gaseous stream treatment	Liquid waste streams
	Commonly used for process off-gas treatment		
	Solutions may simply be water or solutions of reagents that specifically target certain compounds		

To choose which treatment technique was the most optimal for the GRS, the Analytical Hierarchical Process (AHP) was used, shown in Fig. 2.

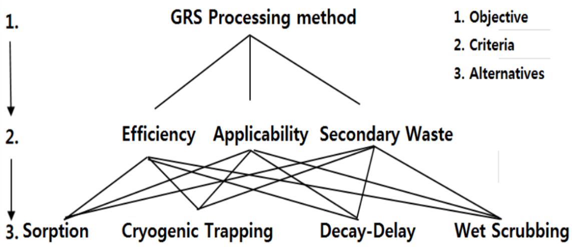

Fig. 2. AHP decision making process.

Table 2. AHP decision making score

Process	Sorption	Cryogenic trapping	Decay/ delay	Wet scrubbing
Score	0.185	0.215	0.49	0.111

The optimal GRS process for the APR 1400 is the decay-delay technique, since it has the highest score of 0.490 according to the AHP, seen in Table 2.

3.2 Building Ventilation Systems

Optimization of the ventilation systems focused on the carbon adsorber since it had the capacity to improve from 90% to 99% efficiency for a non-safety related subsystem, as seen in Table 3.

Table 3. BVS components efficiencies [1]

Parameter/ Efficiency	Safety-Related	Non-Safety Related
Pre-filter	90 - 95	85
HEPA filter	99	99
Carbon adsorber	99	90

4. Dose Reduction Estimation

For source term estimation of the optimized GWMS a decontamination factor was applied, see Equation 1. With an improvement of a 90% to 99% efficiency carbon filter installation, DF improved from 10 to 100.

$$DF = \frac{Initial\ specific\ radiaoctivity}{Final\ specific\ radiaactivity} \quad (1)$$

The source terms were entered into ENDOSE-ATM and ENDOSE-G software and calculated dosage estimation, for both before and after improvements to the carbon filter. Dose estimation was conducted as follows (1) decide exposure pathways, (2) meteorological data analysis, (3) define atmospheric stability, (4) perform radiological dose assessment using Endose-ATM and Endose-G [3].

Table 4. Dose estimation

Pathway	Before (mSv/yr)		After (mSv/yr)	
	Plume	Ground	Plume	Ground
E-dose	1.98E-03	4.83E-05	9.88E-04	4.68E-05
GI-tract	1.35E-03	4.69E-05	7.49E-04	4.55E-05
Bone	3.48E-03	6.59E-05	1.46E-03	6.38E-05
Liver	1.54E-03	4.57E-05	8.23E-04	4.44E-05
Kidney	1.57E-03	4.63E-05	8.22E-04	4.49E-05
Thyroid	1.88E-03	4.75E-05	9.45E-04	4.61E-05
Lung	1.72E-03	4.74E-05	9.08E-04	4.60E-05
Skin	3.08E-02	8.34E-05	1.23E-02	7.72E-05

5. Results and Conclusion

The existing APR-1400 GRS decay-delay technique was found to be an optimal waste treatment method. Employing 99% efficiency carbon adsorbers in the BVS may result in negligible ground pathway reduction but also resulted in significant plume release pathway dose reductions shown in Table 4. This behavior was expected due to gaseous release having more impact on plume release rather than ground pathway. The simulation results confirmed that optimization can result in reduced dose releases. It is recommended to incorporate these optimizations in the APR-1400, this would result in Kr, Xe, and I dose reduction, from the Kori site.

6. Acknowledgments

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7. REFERENCES

[1] KEPCO, KHNP, "*Design Control Document Tier2 Chapter 11: Radioactive Waste Management*," United State Nuclear Energy Commission, 2014.

[2] IAEA, "*Treatment of Radioactive Gaseous Waste*," International Atomic Energy Agency, Vienna, 2014.

[3] W. T. Hwang, "*Overview of Radiological Dose Assessment from Routine Releases of Radioactive Effluents,*" Ulsan, 2016.