Performance Improvement of Liquid Waste Management System for APR1400

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1. Introduction

Liquid radioactive waste in Nuclear Power Plants (NPP) is mainly generated from the cleanup and maintenance process of reactor coolant and related systems containing radioactivity. Due to global concerns to reduce the release of radioactive and other toxic substances into the environment, various improvement/upgrading of processes and technologies have been studied. Consequently, new and improved materials and processes are under consideration and development in various countries to improve decontamination and minimize costs. This study discusses the possible performance improvement of the existing Liquid Waste Management System (LWMS) of APR1400 without total overhaul of the system.

2. Methodology

2.1 Technological Development of LWMS

The latest Korean NPPs after Shin Kori 1&2 have adopted the Reverse Osmosis (RO) technology for the processing of liquid radioactive waste. Installing an ion-exchange resin after the RO module minimizes the concentration of the radioactive materials contained in the effluent.

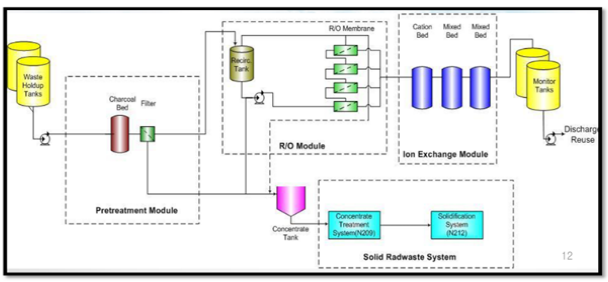

Fig. 1. Schematic Diagram for LWMS.

2.2 Proposed System Improvements

2.2.1 Increasing Selectivity

Chemical additions are designed to enhance the removal of soluble ionic species by standard and ion specific exchange media and the removal of colloids by filtration. Chemical precipitation / co-precipitation process is employed for the treatment of radioactive liquid waste associated with higher dissolved solids and varying chemical and radiochemical composition.

Table 1. Ion selectivity of cross-linked cation resins

DVB%	4%	8%	12%	16%
Li	0.9	0.85	0.81	0.74
H	1.0	1.0	1.0	1.0
Co	2.65	2.8	2.9	3.05
Cs	2.0	2.7	3.2	3.45

Table 1 above shows that the affinity for Cs over H+ and Li+ ions increases with the cross-linking of the strong acid cation exchange resin. Therefore, if high Divinylbenzene(DVB) cross-linking resin is applied to ion exchanger module after RO module, the decontamination factor can be increased.

Highly macroporous strongly basic resins have been used to remove the metal oxide colloids in nuclear plants.

2.2.2 Optimal Operation Conditions

Performance of the RO is influenced by many variables like temperature, pressure, pH, etc.

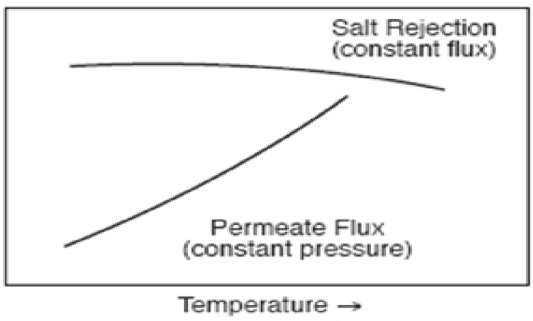

Fig. 2. Effect of Feedwater Temperature on Flux and Salt Rejection.

As water gets colder it gets thicker and the flow rate out of a membrane is lower. As water gets warmer it gets thinner and the flow rate coming out of a membrane increases.

Assuming that the operating temperature of the module goes down to about 10℃, the performance of RO will be reduced by 50% below the design flow rate including the impact of the existing use of RO module. This may cause the unnecessary replacement of RO membrane.

3. Evaluation

3.1 Dose Reduction

Annual emission amount change of radioactive waste by the improvement of LWMS is calculated by the PWR-GALE code. Off-site Dose by the annual emission amount change will be calculated by the ENDOS-L code.

Decontamination factors of LWMS are considered as each LWMS components of R/O module and IX for isotopes.

$$DF = \frac{Initial\ activity}{Final\ activity\ following\ treatment} \quad (1)$$

Expected Radioactive Source Terms modified by improved DF of LWMS will reduce offsite dose compared with original offsite dose. When improvements are applied, maximum individual dose and organ dose are reduced to 4.61E-05 and 6.88E-04 mSv/yr from 5.41E-05 and 7.00E-04 mSv/yr, respectively. This result indicates that maximum individual dose is reduced by 14.8% from original values.

3.2 Solid Waste Generation Reduction

Amount of waste drums is determined by the volume and frequency of membrane replacement. Annual disposal cost for membrane can be calculated through the following equation using the amount of the waste drum and the replacement cycle.

$$Annual\ disposal\ \mathrm{cost} = DC * \frac{TM}{200L * RP} \quad (2)$$

* DC : Disposal cost of a drum
* TM : Total volume of spent membrane
* RP : Replacement period(Year)

Therefore, extending replacement period of membrane will reduce solid waste generation and expected disposal cost. The original disposal cost of RO membranes per year is estimated 13,855,966 won.

When replacement period is extended to 27 months, the annual investment for material selection is ₩513,333. Total improvement can save money equivalent to ₩4,618,656 and net benefits will be ₩4,105,322 per year. This result shows that annual disposal cost is reduced by 29.6% from original cost.

4. Conclusion

This paper aimed at improving the current APR 1400 LWMS. LWMS improvements proposed by the project are expected to be beneficial in terms of dose reduction and solid waste generation. Although the exact effectiveness of improvement in terms of DF cannot be quantified, the impact of improvement can be predicted from reference documents and experience. Future work should therefore include follow-up work designed to measure real DF changes after improvements.

The described improvements do not involve equipment modification, and hence, can be applied in the currently operating NPPs. And it will be helpful to reducing offsite public does and operating cost of NPP.

5. Acknowledgments

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6. REFERENCES

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