Regulatory requirements for radioactive effluent control in U.S. nuclear power plants

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1. Introduction

Nuclear power plants (NPPs) take measures necessary to keep the amount of radioactive effluents and dose as low as reasonably achievable (ALARA). In this regard, radiation monitors are installed to monitor radiation concentration of the effluents from NPPs and control the release. More cautionary methodology is to be developed for determining alarm set points of the effluent monitors for a site with multiple reactors.

Central Research Institute of Korea Hydro & Nuclear Power Co., Ltd conducts a research project to develop the standards for alarm set-points of radioactive effluent monitors. In this regard, this paper describes U.S. regulations pertinent to radioactive effluent control in nuclear facilities in order to help understand Korean effluents control regulations.

2. Methods and Results

2.1 10 CFR Part 20

10 Code of Federal Regulation (CFR) Part 20 "Standards for protection against radiation" provides the limits of concentration of radionuclide contained radioactive effluents at the boundary of unrestricted area, when radioactive materials released from nuclear facilities to the environment so that the concentration does not exceed the specific concentration for radionuclide depending on the type of release (gaseous and liquid) [2].The concentration of radionuclide results in 0.5 mSv of annual dose to the public who are exposed continuously to radioactive effluents (gaseous or liquid) at the boundary of unrestricted area.

For the case of gaseous release (particle, iodine), the concentration of radionuclide can be calculated by applying weighting correction factor 300 to the following equation:

$$\mathrm{DAC} = \frac{\mathrm{ALI(\mu Ci)}}{(2000\ hrs\ \times 60\ \mathrm{min} \times 2 \times 10^4 ml/\mathrm{min})}$$

$$= \frac{ALI}{2.4 \times 10^9}\ \mu Ci/ml$$

The correction factor 300 considers the differences between worker and public in dose limit (1/50), respiration rate and activity time (1/3), and dose coefficients by age group (1/2).

For the case of liquid release, the concentration of radionuclide can be calculated by applying annual intake drinking water of reference man (7.3×10^5 ml), deference of dose limit (1/50) between worker and public, and deference of dose coefficients by age group (1/2) to the ALI.

Furthermore 10 CFR Part 20 requires reports within 30 days after occurrences, if level of concentrations of effluent exceeds 10 times of the value [2].

2.2 40 CFR Part 190

40 CFR Part 190 provides environmental radiation protection standards for nuclear power operations [3]. To protect environment from nuclear fuel cycle facilities U.S. Environmental Protection Agency (USEPA) requires that the public dose due to radioactive materials does not exceed a certain level. 40 CFR Part 190 is considered to be important regulation for the management of radioactive effluents since it provides the criteria for the public dose to be received due to the radioactive effluents although it is not directly related to the radioactive effluent concentration.

Table I shows dose standards of 40 CFR Part 190 for uranium fuel cycle facilities [3]. These values apply to a NPP site but not to each NPP unit. Particularly, 40 CFR Part 190 is recited in 10 CFR Part 20.1301(e) and is regulatory requirement that must be met in order to control radioactive effluents and comply dose of public from nuclear facilities.

Table I. Dose standards of 40 CFR Part 190 for Uranium Fuel Cycle Facilities

Dose	Limit per site
Whole body	0.25 mSv y^{-1}
Thyroid	0.75 mSv y^{-1}
Any other organ	0.25 mGy y^{-1}

2.3 10 CFR Part 50

10 CFR Part 50 describes general design criteria for NPPs. Criteria related with radioactive effluents are described in "Criterion 64 - Monitoring radioactivity releases" [4]. Criterion 64 requires NPPs to equip

monitoring systems for the reactor containment atmosphere, spaces containing components for recirculation of loss-of-coolant accident fluids, the plant environs, and effluent discharge paths for radioactivity that may be released during both normal operations, including anticipated operational occurrences and postulated accidents.

Particularly, 10 CFR Part 50 Appendix I provides numerical guides for design objectives and limiting conditions for NPP operation to meet the criterion "ALARA" for the phase of construction permit. The design objectives provided in 10 CFR Part 50 Appendix I are represented in table Ⅱ [4].

Table Ⅱ. Design objectives of Appendix I to 10 CFR Part 50 for radioactive effluents released from each nuclear power reactor

Dose	Type of effluents	Limit per unit
Total body from all pathways	Liquid	0.03 mSv y^{-1}
Any organ from all pathways	Liquid	0.1 mSv y^{-1}
Gamma dose in air	Noble gas	0.1 mGy y^{-1}
Beta dose in air	Noble gas	0.2 mGy y^{-1}
External dose to total body of an individual	Noble gas	0.05 mSv y^{-1}
External dose to the skin of an individual	Noble gas	0.15 mSv y^{-1}
Dose to any organ from all pathways	Radioiodine & particulates in gas (including ^{3}H & ^{14}C)	0.15 mSv y^{-1}

3. Conclusions

The control of radioactive effluents released from U.S. NPPs is conducted by two aspects. First one is the radioactivity concentration in effluents, and the second is dose of member of public due to radioactive effluents released from NPPs. 10 CFR Part 20 provides the limits for concentration of radionuclide in radioactive effluents released from nuclear facilities at the boundary of unrestricted area. 40 CFR Part 190 provides dose standards of member of public at the boundary of unrestricted area of NPPs. Furthermore, 10 CFR Part 50 Appendix I provides design objective doses to meet the criterion "ALARA" for the phase of construction permit. Table Ⅲ indicates parameters which are used in 10 CFR Part 20, 40 CFR Part 190, and 10 CFR Part 50 Appendix I [1].

Table Ⅲ. Parameters associated with dose calculation

Parameter	10 CFR Part 50, Appendix I	10 CFR 20.1301(e)
Dose	Whole body, max of any organ, Gamma air, and beta Air	Whole body, max of any organ, Gamma air, and beta Air
Basis	ICRP Publication 2	EPA 40 CFR Part 190 (ICRP Publication 2)
Location	Unrestricted Area	Unrestricted Area
Individual receptor	Real person/exposure pathway	Real person/exposure pathway
Origin	Liquid and gas radioactive waste	Liquid and gas radioactive waste Direct radiation Accumulated radioactive material not already included in dose estimates
Radioactive material	Licensed only	Licensed and unlicensed
Period	Current year	Current and prior years' operation

U.S. NPPs control the concentration of radioactive effluents released from the site to the unrestricted area will be limited to 10 times the effluent concentration levels of 10CFR20, Appendix B. This means that U.S. NPPs have relatively enough margins for setting radioactive effluent monitors alarm set point, compared with Korean NPPs which apply 1 mSv annual dose. Particularly, some of the design objectives and dose standards recommended in 10 CFR Part 50 and 40 CFR Part 190 are quoted in article 16 (Prevention of Hazards to Environment) of Nuclear Safety and Security Commission (NSSC) notice 2016-16 "Standards for Radiation Protection, etc." of Korea. This paper will be useful for understanding the regulations pertinent to radioactive effluent control at Korean NPPs.

REFERENCES

[1] Korea Hydro & Nuclear Power Co., Ltd. Current status of regulatory requirements for the determination of set-points for radioactive effluent monitors at pressurizer water reactors, Technical Correspondece, 2017-50003339-0421 TC; 2017.
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[3] U.S. Environmental Protection Agency. Environmental Radiation Protection Standards for Nuclear Power Operations. Washington, DC: U.S. Government Printing Office; 40 CFR Part 190; 1977.
[4] U.S. Nuclear Regulatory Commission, Domestic Licensing of Production and Utilization Facilities. Washington, DC: U.S. Government Printing Office; 10 CFR Part 50; 1956a.