DEVELOPMENT OF SPECIFIC SAFETY REQUIREMENTS FOR RADIOLOGICAL PROTECTION OF KOREAN NEXT GENERATION REACTORS

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ABSTRACT

In this work specific safety requirements for radiological protection have been developed for Korean Next Generation Reactors (KNGR). Specific requirements of radiological protection, consistent with safety objectives, safety principles, and general safety criteria in the regulatory framework will be used to assess the safety of the KNGR. The requirements are divided into two categories, i.e., common design requirements and system design requirements. The common design requirements of ALARA are related to quantitative optimization. Key safety issues have also been derived, which should be reflected appropriately in relevant safety requirements. They are currently the incorporation of ICRP 60 recommendations and the monetary values for ALARA implementation. The system design requirements of radiation protection facilities are divided into those for shielding, radiation monitoring system, radiation management facilities, and systems interfaced with other systems.

INTRODUCTION

Background

The international Commission on Radiological Protection (ICRP) issued new concepts for the system of radiation protection in 1990 as ICRP publication 60. Recently the International Atomic Energy Agency (IAEA) issued new Basic Safety Standards (Safety Series No. 115). In addition we are obliged to implement the radiation protection provisions under the convention on nuclear safety of the IAEA. To be in line with the current international trends in radiation protection, the Korea Institute of Nuclear Safety (KINS) staff has been developing Korean radiation laws and regulations which will be applied to Korean Next Generation Reactors (KNGR). Korean radiation protection laws and regulations, which are a part of the Atomic Energy Act and its supplements, are based on the concepts and principles of ICRP publication 9 (1966). Also they incorporate some part of the recommendations in ICRP publication 26 (1977). Therefore, there is an urgent need to update our national radiation protection regulations.

Structure of the Regulatory Requirements for the KNGR

The radiation protection requirements for the KNGR are being developed under the structure of safety regulatory requirements for the KNGR. The top tier requirement are the radiation protection objectives and are based on the new ICRP recommendations. The second tier requirements are principles of radiation protection and principles of emergency preparedness. Third tier requirements are general safety criteria, the criteria on ALARA, on the dose limitation, on the radiation protection facilities and equipment. Specific safety requirements are the technical detailed provisions which should be implemented to satisfy the safety principles (Lee et al. 1996a).

The safety objectives for radiological protection require that the radiation exposures to plant personnel and public should be maintained to be as low as reasonably achievable (ALARA) and the radiation exposure

dose should not exceed the dose limits. Also, radiological consequences of an accident of the nuclear power plant should be mitigated. Radiation exposure shall be maintained as low as reasonably achievable and be kept below dose limits in operational states and decommissioning of nuclear installations. The radiological consequences due to accidents shall be ensured to be mitigated (Yune et al. 1996a).

Safety principles in achieving the safety objectives require that the nuclear power plant should be designed and constructed based on sound radiological protection principles and a radiation protection program should be established and implemented during operation and decommissioning. To ensure radiation exposure to the workers and the public as low as reasonably achievable, nuclear installations shall be designed and constructed based on sound radiation protection principles, and radiation protection programs shall be established and implemented during operation and decommissioning (Yune et al. 1996b).

The general safety criteria require the essential features of radiological protection such as ALARA, dose limitation, and radiation protection facilities. An analysis of the plant design and system of operation shall be carried out to predict the radiation doses likely to be received by workers and the public, and presented to demonstrate that the plant will meet the specific ALARA requirements provided as the specific safety requirements of the KNGR. No person shall receive a radiation dose greater than the dose limits from all sources of radiation. At present the dose limits of 20 mSv/yr for workers and 1 mSv/yr for the public are positively considered. Radiation protection facilities and equipment are the features related directly to the radiation protection to maintain the occupational doses ALARA and not exceed the dose limits. These should contain the provisions for the control of access into radiation and contaminated areas; provisions for shielding to reduce radiation level; provisions of monitoring radiation level and concentration of radioactive materials during normal and accident conditions and providing sufficient information to the control room and proper control position; provisions for decontamination of personnel and equipment; ventilation systems with appropriate filtration to ventilate contaminated air and to filter airborne radioactive substances (Lee et al. 1996b).

SPECIFIC SAFETY REQUIREMENTS

In this paper, approaches, key issues and some differences between the existing Korean regulations and the proposed specific requirements are presented. The draft specific requirements are tentatively considered to be the ministerial notices of the minister of science and technology which are the lowest level in the Korean regulatory framework. In developing the draft specific requirements we have consulted current Korean atomic energy laws, U.S. NRC 10 CFR 50, 10 CFR 20 as well as IAEA safety series.

Specific requirements of radiological protection, consistent with safety objectives, safety principles, and general safety requirements will be used to assess the safety of Korean next generation reactors and these requirements are divided into two categories, i.e., common design requirements and system design requirements.

The common design requirements should be reflected in the design of NSSS and BOP. We have developed two specific common design requirements of radiological protection. They are ‘ALARA’ and ‘Radiation Source Term’. The current Korean Atomic Energy Act article 97 requires that the licensees of nuclear facilities should take measures to maintain radioactive material releases and radiation exposures to be ALARA as the presidential decree specifies. However, no specific regulations about the implementation of ALARA have been established in the current regulatory framework. The proposed ALARA requirements for KNGRs are related to quantitative optimization, monetary value of radiation exposure, and standards of occupational collective dose. Some numerical values for these requirements will then have to be developed.

For the radiation source term requirements we will develop evaluation criteria for radiation sources in the design of shielding and ventilation systems, radioactive waste management systems in normal and abnormal conditions as well as the radiation source term for design basis accidents and severe accidents. Key safety

issues have also been derived, which should be reflected appropriately in relevant safety requirements. They are the incorporation of ICRP 60 recommendations and the monetary values for ALARA implementation.

For the system design requirements of radiation protection facilities, the requirements are divided into those for shielding, radiation monitoring, dose assessment, radiation management facilities and equipment, and finally requirements interfaced with other systems. The requirements interfaced with other systems and areas are those of ventilation, effluent monitoring, sampling and analysis, off-site dose assessment, and environmental monitoring. In developing these draft specific requirements, we have emphasized performance criteria rather than prescriptive criteria as basic requirements in radiological protection as well as requirements of radiological protection programs, not just systems and equipment. Thus the proposed requirements of radiological protection programs will include policy, organization, systems and equipment to implement the policy, qualified manpower, and procedures.

COMMON DESIGN REQUIREMENTS

ALARA requirements

Nuclear facilities should be designed for the station personnel and the nearby public such that the radiation exposures expected during normal and abnormal state and dangers expected under design bases accident and severe accident conditions will be maintained as low as is reasonably achievable from the cost-benefit point of view considering economic and social parameters. For this, a protection plan should be provided including all the practical provisions. The required engineered methods should be reflected, and adequacy of the design should be shown through the cost-benefit analysis by quantitative methods. Monetary values of radiation exposure required for quantitative cost-benefit analyses should be developed to implement the ALARA requirements.

This provision provides the specific safety standards of the ALARA criterion prescribed in General Safety Criteria. If the doses to the workers and the public, predicted by the analysis of the overall plant design, are less than the safety standards and the methodology of the prediction is appropriate, it may be judged that the doses are ALARA. However, if the requirements are not satisfied, it shall be demonstrated the doses to the workers and to the public are ALARA by the cost-benefit analysis. The provision has been developed as:

The radiation doses likely to be received by workers and members of the public from the operation of the nuclear power plant should be less than

For workers;

Individual doses	*5 mSv during a year*
Average doses	*2 mSv during a year*

For members of the public *0.02 mSv during a year.*

If the above figures are not satisfied, it shall be considered whether the right balance has been struck between the costs and benefits (Lee et al. 1996c).

As engineering measures to ensure the exposures ALARA, the following aspects shall be considered in the design of nuclear installations:

(1) Reduction of radioactive sources, in particular, minimization of activated corrosion products by employing suitable materials for systems and components,

(2) Appropriate layout and shielding of structures, systems, and components containing radioactive materials,

(3) Prevention of leakage and spread of radioactive materials within the nuclear installations and reduction of radioactive material releases to the environment, and

(4) Appropriate zoning according to expected dose rate for the exposure control of workers in operational states and minimization of personnel activities in controlled areas.

SYSTEM DESIGN REQUIREMENTS FOR RADIATION PROTECTION

Shielding

In radiation shielding, provisions for verification of radiation shielding analysis code and analysis methods, for radiation shielding material, particularly for specification criteria of the concrete shields, for radiation shielding design, and radiation shielding test are being considered. Especially the shielding design should be made such that the resultant radiation level will not exceed the design objective values of doses and also consider the buildup of dose rates during the life of the nuclear power plant. The design of shielding should consider the potential production of local high dose rates due to streaming effects. The shielding design should consider the provisions for the loss of the liquid and variation of the liquid level when a liquid is used as shielding material.

Radiation Monitoring

Effective monitoring programs should be established in the reactor facilities to provide the information of the on and off-site radiological conditions and to monitor the radiation exposure for workers and the public. Monitoring programs should include radiation monitoring devices and measurement equipment of appropriate performance, radiation monitoring procedures and records, reports, and custody systems. Radiation monitoring systems and their related components should be able to guarantee reliability. Radiation measurement and monitoring devices should be calibrated every corresponding period (Lee et al. 1996d).

(1) Effective radiation monitoring programs for radiation protection of workers and the public should include monitoring of workers, monitoring of area, effluent monitoring, environmental monitoring, and process monitoring. Appropriate monitoring systems conforming monitoring purposes should be provided to perform these monitoring programs. Monitoring systems should have the equipment which can detect the radiation concentration and radiation dose rate, and alarm automatically when these exceed the limits. Operational reliability should be assured under the normal operation and accident conditions.

(2) Area radiation monitor device which measures the radiation dose rate continuously should be fixed at a proper control area to monitor the radiation exposure of workers. Safety-related monitoring devices among the area radiation monitors monitoring devices should have capability to gear related safety systems when it monitors radiation level exceeding alarm limits. Airborne radiation monitoring device should be provided at the location where workers reside or concentration fluctuation of the airborne radioactive materials is expected.

(3) Process monitoring systems should be provided to monitor the abnormal radiological conditions in reactor facility process.

(4) Liquid and gaseous effluents monitoring systems should be established to monitor the pathways of radioactive materials to environment under the normal operation or accidental conditions. Alarm system should be operated when the radiation material concentration during ventilation or draining

exceeds the effluents control limits, and release blockage and alternative management systems should be operated when necessary.

(5) Appropriate monitoring devices should be established to monitor the radiation level or airborne radioactive material concentration within the reactor site boundary.

(6) Reactor facilities should have equipment which can rapidly sample radioactive material concentration and sample of impurities in the primary and secondary systems, analyze, and measure radioactivity. Sampling systems should be able to extract coolant sample in the primary system within the range of not causing excess radiation exposure to workers during postulated accidents, and should have equipment to extract air sample in containment building.

(7) Equipment which provide information for important radiation dose rate, radioactive material concentration of the area radiation monitor, process, and effluents monitoring device to the main control room and the radiation management department should be provided.

Dose Assessment

The programs which assure the methods and procedures of evaluating individual dose of workers, collective dose, and public exposure to verify optimization of exposure for all activities which contribute the occupational exposure and in which the dose assessment results are reflected should be provided in the reactor design (Lee et al. 1996e).

Radiation Management Facilities

Organization, facility, equipment, and procedures necessary to prevent hazards for workers from radiation exposure and to perform the optimization of radiation exposure under the normal operation and postulated accidents of the reactor facilities should be provided (Lee et al. 1996f).

(1) An organization in charge of radiation safety control should be provided in reactor facilities. The organization staff should have appropriate qualification for the corresponding radiation protection tasks.

(2) Facilities that limit the entrance to the control area should be established in the reactor facilities and a sign indicating a control area should be presented.

(3) Individual monitoring devices (individual dosimeter) should be equipped to monitor the individual exposure radiation dose of the occupants working in the control area of the reactor facilities. Programs to evaluate internal exposure dose should be assured, and the procedures and methods include air sampling, bioassay method, and whole body counting.

(4) Appropriate protection equipment to reduce the internal exposure through respiration should be equipped. It includes officially approved individual respiratory masks.

(5) Portable radiation measurement devices and air sampling devices necessary for the radiation safety control in a control area should be provided.

(6) Radiation surveys should be performed using calibrated measuring devices. Appropriate calibration sources and calibration equipment based on the national standard should be provided for calibration of radiation measuring devices.

(7) Surfaces of walls, floors, and other materials having potential for contact with a person among the locations in a control area should be selected to prevent contamination. Facilities for removing contamination by radioactive materials should be available. Equipment removing the contamination or reducing the contamination level below the limits by decontamination should be provided when a

contamination level exceeding limits is detected through measurements of surface contamination for workers and equipment at the time of the control area.

(8) Emergency protection devices should be provided to reduce the radiation exposure of workers, for accident mitigation or recovery work during radiation emergency.

CONCLUSIONS

Up to now, the systematic whole set of radiation protection requirements for the regulation of the KNGR has been established, putting greater emphasis on the implementation of ALARA than on the limitation of individual doses. This approach is consistent with the recent international trends in radiological protection community. For further works, we are going to develop the detailed provisions on the specific safety requirements of the KNGR, including the provisions on the monetary values of a unit exposure, radiation sources terms for normal and accident conditions as well as the system design requirements for the systems interfaced with other systems.

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KEY WORDS

KNGR, Radiological Protection, Specific Safety Requirements, ALARA, Dose Limits, ICRP 60