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New Method for Classification of Radiation Devices for Industrial Use

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1. Introduction

Every radiation generating devices or devices containing radioactive isotopes (Radiation Devices) should get a design approval from the competent authority, the Ministry of Education, Science & Technology (MEST). Radiation Devices has been sorted and approved according to the design and structural criteria set by regulatory body. New classification method of radiation devices has been suggested to improve the safety control and effectiveness of design approval of radiation devices. Failure Mode and Effects Analysis (FMEA) method was used to evaluate potential accident factors involved in operation of radiation devices. The overall effect of failures on the radiation devices was estimated and the total risk factor for the model radiation device was determined.

2. Methods and Results

2.1 Design Approval of Radiation Devices

Radiation devices should meet following standards to get design approval certificate; 1) Radiation equipment shall not be feared that the radiation source is easily released or the radiation injury occurs. 2) The design and structure of the radiation equipment shall conform to the safety standards set in the domestic regulations. Radiation devices has been sorted and approved according to domestic regulation MEST Notice No. 2008-23, Standards for design approval and inspection of radiation equipments. Items for design criteria include shielding, safety interlock, emergency stop, control of radiation emission, warning system etc. Radiation devices have several structure types, such as, full protection, self protection, cabinet, unattended isolation, portable and open type.

2.2 Re-classification of Radiation Devices

Design approved radiation devices were categorized according to their design purposes and safety related features of radiation devices such as structures, function, operating energy, accident doses were analyzed. Main items considered include device performance, radiation dose at maximum operating condition, safety features, operation procedures, potential exposure dose in accident condition etc. Radiation devices for industrial application were classified into Class I through Class IV through overall evaluation of safety features and exposure dose in accident condition. The representative devices were selected for each class and essential safety requirements have been suggested for each class of radiation devices.

Table 1.Classification of Radiation Devices

Class	Structure Type	Operating Voltage	Accident Dose Criteria	Required Safety Officer
Class Ⅰ	Full Protection Self Protection	< 50kV	Terminal Organ : < 1mSv Eye : < 1mSv Body : < 1mSv	-
Class Ⅱ	Full Protection Self Protection Cabinet Unattended Isolation Portable Open	50kV - 170kV	Terminal Organ:< 500mSv Eye : < 150mSv Body : < 50mSv	-
Class Ⅲ	Full Protection Self Protection Cabinet Unattended Isolation Portable Open	> 50kV	Terminal Organ:> 500mSv Eye: > 150mSv Body : > 50 mSv	Supervisor or General Licensee of Radiation handling
Class Ⅳ	Unattended Isolation Portable Open	> 170kV	Body : > 50 mSv	Supervisor of Radiation handling

To evaluate potential accident factors involved in operation of radiation devices, Failure Mode and Effects Analysis (FMEA) method was used. FMEA method is a procedure for analysis of potential failure modes within a system for determination of the effect of failures on the system. Experience and knowledge of designer or manufacturer of radiation devices were

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considered to estimate risk factors causing failure of radiation devices. Errors or defect types and failure frequency during operation of radiation devices were examined and also safety features of design approved radiation devices were analyzed.

Potential failure modes in radiation devices were analyzed and each failure mode except accident was given a risk factor from 0(no danger) to 1(critical). Accident failure mode was given a risk factor from 0(no danger) to 10(critical) according to the exposure dose in accident condition. As an example, risk factors for radiation emission control of radiation devices were given in Table 2.

Table 2.Risk Factors for Radiation Emission Control

Category	Function	Specification	Factor	Max. Factor
Radioisotope Device	Emission Detection	Equipped	0.2	0.4
		Not equipped	0.4	
	Position check	Equipped	0.1	
		Not equipped	0.3	
	Time control	Equipped	0.1	
		Not equipped	0.3	
Radiation Generating Device	Detection Emission	Equipped	0.3	0.6
		Not equipped	0.6	
	Time control	Equipped	0.2	
		Not equipped	0.4	

The overall effect of failures on the radiation devices was estimated and the total risk value for the representative radiation device of each class was determined by summation of specific risk factors.

Table 3.Results of Classification and Measurement

Class	Model Devices	Estimated Risk Value by FMEA	Leakage Radiation in Normal Operation (μsv/hr)	Exposure Dose in Accident Condition (mSv)	
Class I	XRF	< 5	< 0.2	Eye, Whole Body	< 0.55
Class II	Baggage Inspection Device	< 5	< 10	Eye	< 1.42
				Whole Body	< 3.41
	Product Defect Inspection Device	< 5	< 0.2	Eye	< 2.8
				Whole Body	< 2.75
Class III	Product Defect Inspection Device	< 10	< 0.2	Eye	< 3.83
				Whole Body	< 3.76
Class IV	Linear Accelerator	> 10	< 2.5	Whole Body	~ 80

Leakage radiation level of the representative device for each class in normal operation condition was measured at 10 cm distance from the surface using typical detection equipments. In an accident condition, radiation exposure dose was measured using TLD and measuring points were determined by simulating accident situations. For the XRF, the representative device of Class I, the leakage radiation in normal operation was less than 0.2 εSv/hr and the measured radiation dose in accident condition was less than 0.55 mSv. Baggage inspection device, the representative device of Class II, can give the leakage radiation up to 10 εSv/h and the accident radiation dose to 3.41 mSv. For defect inspection device for various mechanical or electronic parts, the representative device of Class III, the leakage radiation in normal operation was less than 0.2 εSv/hr and the measured radiation dose in accident condition was less than 3.83 mSv. For Class IV, the representative device is linear electron accelerator of 9 MeV and the neutron dose was measured using BF_3 moderating detector. The leakage neutron dose in normal operation was less than 2.5 εSv/h and the maximum accident dose measured with BF_3 detector has reached to 80 mSv.

Determined total risk values were 1.9 for X-ray Fluorescence (XRF) of Class I, 3.15 for baggage inspection device of Class II, 3.55 for defect inspection device of Class III and 12.7 for linear electron accelerator of Class IV.

3. Conclusions

Radiation devices for industrial application were classified into Class I through Class IV considering the device performance, measured radiation dose at maximum performance, required safety mechanism, operation procedures and anticipated accident dose from accident scenario etc. To evaluate potential accident factors involved in operation of radiation devices, Failure Mode and Effects Analysis (FMEA) method was used. The overall effect of failures on the radiation devices was estimated and the total risk values for the model radiation device of each class were determined. It is expected that new method for classification and risk estimation of radiation devices can be applied to the design approval procedures for radiation devices.

REFERENCES

[1] W.K.Cho et al., ñKINS/RR-709: Evaluation of Key Issues on the Safety Regulation of Radiation Sources for Industrial and Medical Application, p.126-150, 2009.