CONCEPTUAL DEVELOPMENT ON THE RADIATION PROTECTION DESIGN BASES FOR EXPERIMENTAL POWER REACTOR

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ABSTRACT

CONCEPTUAL DEVELOPMENT ON THE RADIATION PROTECTION DESIGN BASES FOR EXPERIMENTAL POWER REACTOR. This paper reports the development of the basic concepts of radiation protection design Experimental Power Reactor (RDE). The report is part of prepared safety documents to obtain construction permits of BATAN RDE prototypes. Nuclear safety be the primary considerations in the RDE design development to protect people and the environment from radiological hazards. One of the safety requirements is radiation protection design requirements which must comply to the issued provisions/regulations, codes and standards. This study aimed to evaluate the readiness and completeness of Indonesian provisions/regulations, codes and standards for developing the conceptual of radiation protection design basic of RDE. The method used was to analyze bases design of radiation protection safety requirement based on Indonesian regulations, identify and review various regulations, codes and standards of HTR have been designed, constructed, and/or operated in various countries, and to evaluate the vacant of regulations, codes and standards necessary to realize the construction of RDE prototype. The results are a vacant map of regulations, codes and standards needed to be developed and issued for develop conceptuals of radiation protection design bases for RDE prototype in Indonesia. The implementation of standard regarding design criteria and location of radiation monitors is most important to be applied for developing of radiation protection design bases of RDE.
Keyword: basic design, radiation protection, nuclear regulation, codes & standards, RDE

ABSTRAK

PENGEMBANGAN KONSEP DASAR DESAIN PROTEKSI RADIASI REAKTOR DAYA EKSPERIMENTAL. *Makalah ini melaporkan pengembangan konsep dasar desain proteksi radiasi Reaktor Daya Eksperimental (RDE). Laporan tersebut merupakan bagian dari dokumen keselamatan yang harus disiapkan BATAN untuk mendapatkan izin konstruksi prototipe RDE. Keselamatan nuklir menjadi pertimbangan utama dalam pengembangan desain RDE agar personil operator, masyarakat dan lingkungan terjaga dari bahaya radiologis. Salah satu persyaratan keselamatan adalah persyaratan desain proteksi radiasi RDE yang harus memenuhi berbagai ketentuan/regulasi, codes and standards yang berlaku. Kajian ini bertujuan untuk mengevaluasi kesiapan dan kelengkapan regulasi, codes and standards Indonesia untuk mengembangan konsep dasar desain proteksi radiasi. Metode yang digunakan adalah dengan menganalisis persyaratan dasar desain proteksi radiasi berdasarkan regulasi Indonesia, mengidentifikasi dan mengkaji-ulang berbagai regulasi, codes and standards keselamatan radiasi berbagai reaktor temperatur tinggi (HTR) yang pernah didesain, dibangun dan/atau dioperasikan dari berbagai negara, dan mengevaluasi kekosongan regulasi, codes and standards yang diperlukan untuk merealisasikan pembangunan prototipe RDE. Hasilnya berupa peta kekurangan/kekosongan regulasi, dan codes and standards yang perlu dikembangkan dan dilengkapi untuk mengembangan konsep dasar desain proteksi radiasi prototipe RDE di Indonesia. Penerapan standar tentang kriteria desain dan lokasi pemantau daerah radiasi pada instalasi RDE merupakan hal yang paling penting untuk dilaksanakan.*
Kata kunci : desain dasar, proteksi radiasi, regulasi ketenaganukliran, codes & standards, RDE.

INTRODUCTION

The study on radiation protection conceptual design for Experimental Power Reactor (RDE) is one element of the activities states on medium term of BATAN Strategic Plan 2015-2019 in the area of energy security priorities. This document planning states that the development of RDE is the main priority activity BATAN within the next 5 years. The output of the activities is constructed a 10 MWth RDE prototype. The Center for Nuclear Reactor

Safety and Technology (PTKRN) in accordance with their mandate, implementing elements activities in the safety and technology development area of RDE. One of these tasks is to prepare the conceptual design documents, to evaluate safety and technology for supporting the prototype RDE construction [1-2].

The radiation protection conceptual design is one element of a complementary document which is prepared as the RDE Technical and Safety Design Document. This study focuses on analysis of the concepts development of the radiation protection design bases for RDE, in order to meet the safety design goals. The safety design goal can be divided into the nuclear safety goal, radiation protection goal and technical safety goal [3-5]. The RDE design target can be achieved if three basic safety functions are fulfilled specifically confinement of radioactive material, control reactivity and heat removal from the reactor core must be fulfilled in all RDE operating conditions that is normal operating conditions, accident and post-accident radiological meet the requirements of radiation protection. Three basic safety functions can be achieved through a strategy by designing RDE implementing defense in depth which ensures that basic safety functions can be achieved reliably with adequate margin to compensate on the probability of failure that can occur due to equipment and/or human error [4]. One element of safety requirements are radiation protection safety directly related to the design implementation on 5 levels defence in depth that are prevention, control, protection against basic design accidents, severe accidents and offsite mitigation.

RDE radiation protection bases design requirements must be comply on the Indonesian regulations such as government regulations (GR) and BAPETEN chairman's regulation (BCR) [3-4] and other provisions that internationally applied. The implementation of provisions, codes and standards in the radiation protection design processess of at various HTR which ever been designed, constructed and operated in various countries at various power levels, are identified, assessed, reviewed and evaluated to be used as starting point for the develop concepts of RDE radiation protection bases design [5-8]. The result is a map of vacant regulations, codes and standards are needed to be developed and equipped for the development of the basic design concepts of radiation protection in the construction of RDE programs in Indonesia. The objective of this works is to get the basic design concepts of radiation protection RDE based on the provisions of the Indonesian GR and BCR, the provisions of the IAEA, and the regulation states designer, build and / or operate HTR. Goal of this study is the completion of the main points of the design bases concepts of radiation protection RDE, based on the evaluation of various provisions of the regulations, codes and standards of industrial countries and the operating HTR designer, as consideration with the essential requirements of radiation protection design of RDE.

METHODOLOGY

This study will focus on the analysis and evaluation various provisions and requirements of radiation protection regulating about the design, construction, operation, and decommissioning of RDE in order to ensure the safety and personnel as well as environmental protection, and security of nuclear materials and installations. The method used is to reviews the various provision of Indonesia radiation protection, IAEA Safety Series, legislation and regulation framework of the designers, builders and operating HTR countries; discuss with the competent persons; evaluate and compare the practical experience of radiation protection design concept preparation; and the followed by analyzing the suitability for the case of Indonesian RDE. The review and analysis result, then used as the radiation protection design considerations for Indonesian RDE. Figure 1 shows the methods for developing the RDE radiation protection design bases conseptual.

The scope of the study as follows: (1) review and analyze the radiation protection provisions on the utilization of nuclear materals and instalatons from designing, constructing, operating and decommissioning, based on Indonesian regulations, international guides and provision (IAEA), and some nuclear industry countries; (2) reviewing the implementation of the provisions/regulations, codes and standards of radiation protection applicable in the phase of design, constructon, operation, and decommisioning of HTR; and(3) summarizes the provisions/regulations, codes and standards which has been available and and compiled those who are not available and which are necessary for the development of the radiation protection basic concepts for the Indonesia RDE.This study aimed to obtain an overview the application of radiation protection key concepts of fundamental bases at various HTR which has been designed, constructed and/or operated on non-commercial grade equivalent to Indonesia RDE plan (10 MWth).

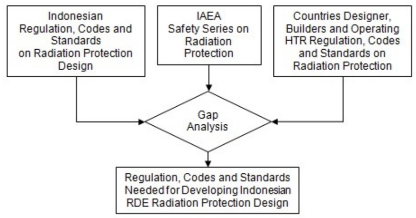

Figure 1. The Methods for Developing Radiation Protections Design for RDE

RESULT AND DISCUSSION

1. The Analysis of Radiation Protection Regulations in Indonesia

The bases of legislation of nuclear energy utilization in Indonesia is an Act No. 10 Year 1997 on Nuclear Energy [9]. In this act, nuclear activity is defined as any activity related to the use, the development and the acquisition of nuclear science and technology and the control of any activity related to nuclear energy. Nuclear energy utilization is related to the life and safety of the people, therefore it must be authored by the state and its beneficial use for national development is aimed to the realize of an equally justice and prosperous people's. Due to the nature of nuclear energy which can not only give advantages but also cause radiation hazards, then every activity related to nuclear energy has to be regulated and controlled by the Government. Nuclear energy is related to the utilization, development, mastery of science and nuclear technology and monitoring of activities related to nuclear power. Use of nuclear energy concerning the lives and safety of people then controlled by the state and utilized as exaggerated for national development. Nuclear energy utilization should be done properly and carefully, and is intended for peaceful purposes and profits as much as possible for the welfare and prosperity of society. In addition to providee benefits, nuclear power can also pose a radiation hazard, because it must be regulated and controlled by BAPETEN. RDE development to be implemented by BATAN should follow basic safety principles of this law and its other radiation safety provisions/ regulations issued by the BAPETEN as regulatory body.

The construction of the RDE is the scope of R&D activities are governed by Chapter III, Article 8 undertaken in the framework of the mastery of nuclear science and technology for safety, security, and prosperity, should consider to mitigate the negative impact of the nuclear power utilization. Any activities related to the use of nuclear energy shall take into account the safety, security and peace, health workers and community members as well as environmental protection. Some GR associated with radiation safety/radiation protection that need to be considered in R&D RDE are as follows: a) GR No. 54 of 2012 on Safety and Security of Nuclear Installations [10]; b) GR No. 2 of 2014 on Nuclear Installation Licensing and Nuclear Materials Utilizations [3]; c) GR No. 33 of 2007 on Safety Ionizing Radiation and the Security of Radioactive Sources [11]. While the BCR that need to be referenced in the development of the basic concepts of radiation protection design include: a) BCR No. 1 of 2011 on the Safety Requirements for the Design of Non-Power Reactor [12]; b) BCR No. 2 of 2011 on Safety Requirements for the Operation of Non-Power Reactor [13]; and c) BCR No. 4 Year 2013 on Radiation Protection and Safety in Nuclear Energy Utilization [14], which sets the value of the dose limit for workers, apprentices and the general public.

Based on the GR No. 102 Year 2000 on National Standardization which is sub-system of the National Standardization System (NSS), primarily the result of accumulation of knowledge, technology and experience of stakeholders are involved in the process of reaching an agreement. The standard approach through two different kinds of approaches, such as (1) based consensus, agreement on a standard draft among stakeholders and (2) based on scientific evidence, the agreement to a standard draft that is based on scientific evidence [15]. The National Standardzation Agency (BSN) has been issued by BSN per May 2016 as much as to 10,708 SNI documents and there are only 9 SNI documents related to radiation safety. From all 9 SNI document are none of these standards relating to radiation protection design [16]. Thus, there is a vacantt standards relating to radiation protection design of non-power reactor. BCR No. 1 of 2011 on the Safety Requirements for the Design of Non-Power Reactor in article 14, it can be used as a solution of unavailable Indonesia provisions/regulations, codes and standards of SSCs, which obliges license holders (PI) implementing the latest of regulations, codes and standards applied to SSCs similar from origin country [11].

2. Basic Provisions of the International Radiation Protection Design

In the process of the RDE nuclear reactor design planned by BATAN, such as design processes other installations, always will be experiencing conditions that are dominated opposition and the balance between fulfilling the safety criteria the one hand, and economic factors on the other. Safety requirements and the demands of the economic aspect are always difficult to be integrated in the realization of a realistic design [17]. However for RDE technology that uses HTR seems these issues can be harmonized in order to obtain the RDE design has inherent safety properties and simultaneously meet economic aspect. Likewise for the development of the basic design concepts of radiation protection RDE which will examine the provisions of the design requirements with reference to the provisions of the IAEA documents. At the international level, generally refers to the provision and IAEA recommendations or ISO that many adopted regulations, codes and standards of ANSI/ ANS, IEC or IEEE which has been developed by the professional community in the USA [18].

In accordance with the basic principles of radiation protection, the development of the RDE design must meet the requirements of the provisions of the Radiation Protection Objective criteria (Radiation Protection Objective) as specified in paragraph 2.4 in the IAEA document, The Safety of Nuclear Power Plants: Design, IAEA Safety Standards Series No. NS-R-1 [19]. This document further explains that the main purpose of the design of the radiation protection installations (RDE) is to ensure that the radiation exposure within the installation at all operating conditions or the conditions of the release of radioactive material from the installation is planned must be maintained below the specified limits that have been set before, and which is as low as achievable (ALARA), as well as ensure the mitigation of the radiological consequences in every accident. Conditionality another design is in accordance with the Safety Objectives Technical (Technical Safety Objective) as specified in paragraph 2.5 that is taking all steps reasonably practicable, to be sure - with a high level of confidence - that all possible accidents have been taken into account in the design of installations, including accidents with a very low probability any, will only result in a small radiological consequences and below the dose limits specified earlier.

Design installation (RDE) should ensure that the dose limits that allowed the regulatory body and the dose set by the ruler of the installation (dose constraints) for radiation workers (site personnel) and the general public will not be exceeded in a given period (monthly, 4 monthly, or yearly) on a variety of operating conditions (normal operation and anticipated operational occurrences and commissioning). Designs must be created for the installation of RDE being built and operated in the future must be able to meet permit requirements limit the dose of the regulatory body and dose limits othorized commitment installation. For workers who did not enter the controlled access area (restricted area and controlled area) dose limits should be set the same as for the general public. The application of the basic principles in the design optimization of radiation protection (RDE) must be addressed so that the entire exposure happens to be below the limits permissible dose and dose iinstalation set by the authorities, as well as exposure to the lowest achievable (ALARA). In the determination of the various economic and social factors to be considered include a) the radiation exposure must be minimized with radiation protection measures in order to charge more for the design, construction and operation will not sacrifice the factors associated with radiation exposure limits; b) the factors that affect a significant difference in radiation exposure received by the various types of work that work in the area of radiation treatment area must be controlled and potentially receive a higher dose should be considered in the design.

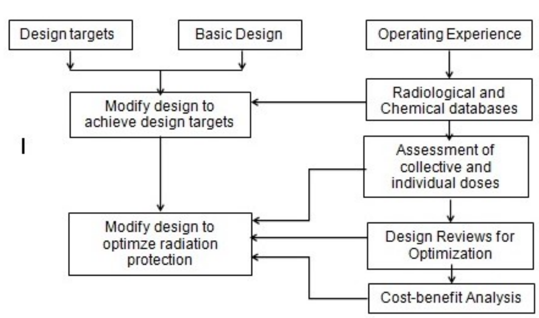

Figure 2. Protection Design Optimization Strategy

In general the design optimization of radiation protection is directed at a series of options design measures such as the type of shield protection, remote operation and auxiliary equipment to minimize radiation exposure time. For this purpose, a variety of design options are worthy to be identified, the criteria for comparison and suitability must be determined and ultimately, the choice should be evaluated and compared. Optimization concept should also apply to design the design features intended to prevent or mitigate the consequences of accidents in installation which could lead to the exposure of personnel workers and / or communities. Graphically the basic concepts of design optimization strategies RDE nuclear plant radiation protection can be presented as in Figure 2 [20].

The radiation protection bases design principles above will be able to ensure the safety of nuclear installations. Nuclear safety can be defined as a variety of ways, but it can be simplified by classifying that nuclear installations are said to be safe when there is no danger of radiation exposure to workers or the public personnel. This means that it does not need their protection needs or evacuation for radiation workers and the public, and is not required mechanical components to implement the protection and evacuation, and exposure to installation personnel are always under the criteria set lower than the limit values of the current international.

Bases design concept of the safety of nuclear installations is based on the basic design concepts of radiation protection with 3 levels [19-21]:

1. The rate limit radiation exposure to personnel radiation workers and the public set by the regulatory body. Liabilities operator (installation ruler) should always try to reduce the dose level by applying the ALARA principle. In other words, the operator must ensure that the level of exposure it receives as far as possible from the limits set by the regulator.
2. There are three basic functions to ensure the safety of the installation, namely a) controlling the reactivity, b) transfers heat from inside the porch and, c) confinement of radioactive material. The third safety function should be implemented well in the design of both the normal and non-normal.
3. Defense plated with principles held to ensure the safety functions work well in non-normal conditions. This principle is applied in order to prevent, control and reduce the incidence of non-normal.

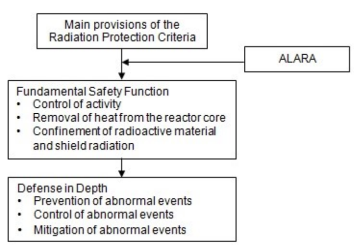

Figure 3. Conceptual of Radiation Protection Design Bases

3. Provisions of the Radiation Protection Design from Several Countries HTR Designer and Operating

The results of the data analysis and information development of basic concepts reactor radiation protection HTR obtained from several countries including America, which developed the GT MHR and EM2, Japan with GT-HTR300, China with HTR-PM and South Africa with the PBMR, and for other countries [23] used as a consideration in the study and analysis of regulations, codes and standards conceptual design of radiation protection required for RDE.

In the United States the main runway on Nuclear Energy legislation includes a) of the Atomic Energy Act of 1954, as Amended (P.L. 83-703); b) Energy Reorganization Act of 1974, as Amended (P.L. 93-438); and c) Nuclear Regulatory Legislation: 109th Congress 1980 (Volume 1, No. 7, Rev. 1, 2nd Session), and (Volume 2, No. 7, 1st Session). At the second level in the form of regulatory matters related to radiation protection forth in 10 CFR - Code of Federal Regulations (CRF), namely a) 10 CFR 20 - Standards for Protection Against Radiation; b) 10 CFR 50 - Licensing of Production and Utilization; and c) 10 CFR 100 - Reactor Site Criteria [24].

with a document Accident Analysis report evaluation assessment NUREG-0800.

At the level of national standards related to the conceptual development of basic radiation protection design RDE is a standard document [25-27]:

- ANSI/ANS-53.1-2011: Nuclear Safety Design Process for Modular Helium-Cooled Reactor Plants
- ANSI/ANS-15.11-2009: Radiation Protection at Research Reactor Facilities, 2009
- ANSI/ANS-HPSSC-6.8.1-1981, Location and Design Criteria for Area Radiation Monitoring Systems for Light Water Reactors

Japanese has been designed and operate HTTR, very active in the research development of high-temperature reactor for hydrogen production. Japan is also developing a reactor design GT-HTRM300 [28]. Legislation Utilization of Nuclear Energy is very strong placing radiation protection provisions in the Convention on Nuclear Safety National of Japan [29-30].

On the lower level of Japan regulation initially were refered/adopted standards from the United States mainly ASME, IEEE, ASNI and then however develop your own. Standards related to radiation protection design that was developed in Japan are adopting standards developed in the United States with Japan JIS nomenclature [31]. For China, which operates HTR-10 and are building the HTR-PM, initially the situation about 30-40 years ago was also do not have adequate regulation infrastructure. China's nuclear safety regulations today [32-33] can be described in a regulatory pyramid as shown in Figure 4.

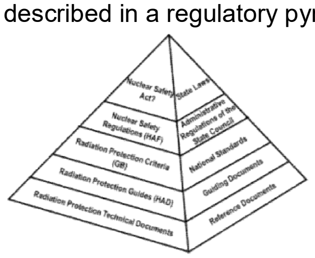

Figure 4. Hierarchy Radiation Protection Regulation in China

4. Conceptual Development of Radiation Protection Design Bases

Assessment legislation and regulatory framework utilization of nuclear energy at the international level through the review of IAEA Safety Series, and in some countries such as the USA - which developed the GT MHR and EM2; Japan - which developed the GT-HTR300; China - with the HTR-10 and HTR-PM; German as a designer HTR-10; and in Indonesia itself examined in order to obtain a picture hierarchy provision and application of codes and standards for the development of the basic design concepts of radiation protection. In summary the results of the comparison of legislation and regulatory frameworks are presented in Table 1 in the appendix.

The monitoring system of radiation safety or radiation protection for workers RDE installation is recommended by applying the standard ANSI/ANS-HPSSC-6.8.1 with the performance requirements of radiation protection monitoring instalation summarized as follows:

- System Accuracy: ± 20% of reading (95% confident level)
- System repeatability: ± 15% of reading (95% confident level) in normal environmental conditions
- System Drift: tidal more than ± 10% of reading (95% confident level)
- System Full Scale Output: when ARM receives a signal 10 times the limit measure, then the channel will still show the full scale for at least 1 hour.

Implementation of radiation protection in the design bases of RDE is equipped with radiation protection monitoring equipment installed in rooms that are accessible radiation workers in accordance with the potential hazards of radiation as shown in Figure 5.

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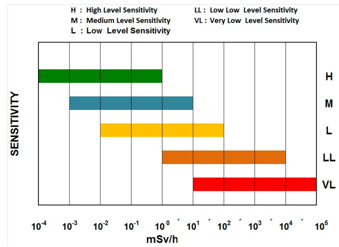

Figure 5. Sensitivity and Measurement Span of Radiation Protection Equipment Monitoring [7]

In general the rooms of the RDE plant based BCR No. 4 in 2013 [14] can be divided into control areas and surveillance areas. The basic design of radiation protection in the area or room that is functionally accessed routinely by radiation workers is an area control zones that can be divided into levels based on the level of risk some planned radiation. For areas or zones accessible routinely need to install radiation monitoring equipment which has the highest sensitivity (H-high sensitivity) with a range of four decades of 10^{-4} mSv/h to 1 mSv/h, and for the subsequent supervision zone needs to be fitted with the same equipment medium sensitivity level and so on, in accordance with the design of a potential radiation hazard in these rooms.

CONCLUSIONS

The assessment and evaluation of legislations and regulations framework that consists of provisions, codes & standards of the radiation protection design from various countries, it were shown that basically the hierarchy regulation is same principles, they puts the radiation safety is the main goal, by implementing the basic principles radiation protection design. Having regard to the guidelines of the IAEA NS-R-4 Safety of Research Reactors, conceptual design of the RDE power 10 MWth are included in recommending research reactors power over 10 MWth, fast reactors, and various types of research reactors that have the facility of experimental equipment such as prop (loop) pressure and high temperature, or cold neutron sources, requires the application of rules and standards of nuclear power plants or additional safety measures compared to other small research reactors. The rules and standards of safety and radiation protection for nuclear power plants should be considered to be adopted and implemented in the radiation protection design of experimental power reactor (RDE). The legislation framework of various countries were reviewed shown that common purpose in nuclear energy utilization, but at the level of regulatory frameworks has been shown different reference, especially at the level of the national standard that refers mosly to the American version (ANS, ANSI, ASME, IEEE, etc) and German standard. Due to RDE based on HTR-10 Germany design constructed and operated in Chinese national standard refers to the American version, it is more appropriate development of the basic design concepts of radiation protection by placing a standard RDE America and Germany become the main reference. This is because in Indonesia has not been found and enforce the necessary radiation protection standards. Standard basic concept of the German radiation protection are 1) KTA 1301.1 (2012-11): "Radiation Protection Considerations for Plant Personnel in the Design and Operation of Nuclear Power Plants, Part 1: Design"; and 2) KTA 1501 (2010-11): "Stationary System for Monitoring the Local Dose Rate within Nuclear Power Plants". While the Americans are also referred to by China is 1) ANSI / ANS-53.1-2011: "Nuclear Safety Design Process for Modular Helium-Cooled Reactor Plants"; and 2) ANSI / ANS-HPSSC-6.8.1-1981: "Location and Design Criteria for Area Radiation Monitoring Systems for Light Water Reactors".

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