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Review of the Status of Low-power Research Reactors and Considerations for its Development

In-Cheol LIM*, Sang-Ik WU, Byungchul LEE, Jaejoo HA
Korea Atomic Energy Research Institute, 989-11 Daedeok-daero, Yuseong-gu, Daejeon, 305-353, Korea
**Corresponding author: iclim@kaeri.re.kr*

1. Introduction

At present, 232 research reactors in the world are in operation [1] and two-thirds of them have a power less than 1 MW. Many countries have used research reactors as the tools for educating and training students or engineers and for scientific service such as neutron activation analysis [2]. As the introduction of a research reactor is considered a stepping stone for a nuclear power development program, many newcomers are considering having a low-power research reactor [3]. The IAEA has continued to provide forums for the exchange of information and experiences regarding low power research reactors [4,5,6]. Considering these, the Agency is recently working on the preparation of a guide for the preparation of technical specification possibly for a member state to use when wanting to purchase a low power research reactor [7]. In addition, ANS has stated that special consideration should be given to the continued national support to maintain and expand research and test reactor programs and to the efforts in identifying and addressing the future needs by working toward the development and deployment of next-generation nuclear research and training facilities [8]. Thus, more interest will be given to low-power research reactors and its role as a facility for education and training. Considering these, the status of low-power research reactors was reviewed, and some aspects to be considered in developing a low-power research reactor were studied.

2. Status of Low-power Research Reactor

2.1 Definition of Low Power Research Reactor

Fig. 1 shows the distribution of research reactors in terms of power [1]. The IAEA research reactor data base (RRDB) uses 1 kW and 1 MW in its categorization by power. The number of research reactors whose power is less than 1 kW is 68 and, those whose power is between 1 kW and 1 MW is 70. When the reactor power is higher than 1 MW, the reactor is cooled by forced circulation of coolant in general, which needs sophisticated cooling systems. In view of research reactor utilization, research reactors whose power are higher than 1 MW provide full scope application in most areas of utilization [9]. Thus, it is believed that 1 MW can be used as the upper boundary of a low-power research reactor [10].

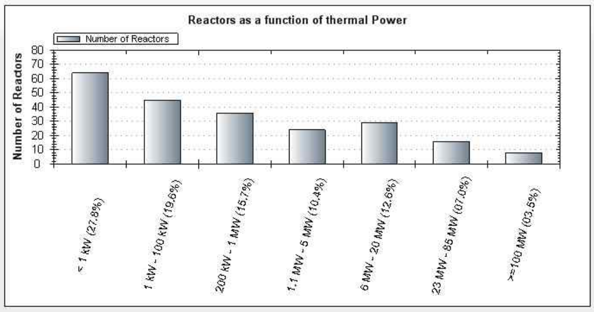

Fig. 1. Number of research reactors in power[1]

2.2 Typical Low Power Research Reactors

2.2.1 TRIGA

TRIGA reactors designed by General Atomic Co are versatile, multipurpose reactors with a world wide distribution of more than 50 facilities. They range in power levels from 18 kW to 14 MW with 250 kW to 1 MW being the most common operating levels [11]. The number of operating TRIGAs whose power is less than 1 MW is 18. TRIGA uses U-Zr-H fuel in a rod shape and it brings a large negative power coefficient and enables the pulse mode. KAERI had two TRIGA reactors but they have been decommissioned [10].

2.2.2 SLOWPOKE

SLOWPOKE was designed by AECL for isotope production and neutron activation analyses at universities, hospitals and research institutes. It is a pool type reactor with a typical power of 20 kW, and samples can be irradiated in a thermal neutron flux of up to 1.0×10^{12} n/cm^2s [12]. Four SLOWPOKEs are operated in Canada and Jamaica has one. SLOWPOKE fuel is a rod type using HEU in U-Al alloy as the fuel material, and the conversion to LEU is being considered [13].

2.2.3 MNSR

MNSR was designed by CIAE and its characteristics are very similar to SLOWPOKE. MNSR is a very useful tool for reactor physics education and training, and for short-lived NAA, therefore, this reactor has become increasingly popular in developing countries as it is the cheapest research reactor presently available [11]. China is operating four MNSRs and it has also been exported to Syria, Ghana, Iran, Pakistan, and Nigeria. It uses HEU in U-Al alloy. Recently, CIAE developed an IHNI which is designed for BNCT based on MNSR. It used 12.5% enriched UO_2 recommended by the DOE through the RERTR program [14].

2.2.4 ARGONAUT

It was designed by ANL to teach reactor theory and nuclear physics. ARGONAUT operates at power levels between 2 W and 300 kW and three ARGONAUTs are in operation. These reactors are graphite reflected, light water moderated, and cooled and operated either with high enriched or low enriched U-Al alloy in a plate geometry. A variety of core configurations are possible ranging from one slab, two slabs (arc or straight slab) or annular core depending on the design and intended use[11].

3. Considerations for the Development of Low-power Research Reactor

When a new engineering facility is developed, it should satisfy the needs of existing customers and should have the potential to create new customers. Thus, the competency and safety will be the primary element.

3.1 Competency

As an output from the 2010 IAEA workshop on the low-power research reactor, several utilization areas, which are believed to have high success indicators, were identified and they include NAA, tracer, training and radiography [5]. Thus, it is believed that these areas should be considered first for the utilization area when the development of a new facility is discussed.

A research reactor is a costly facility and the coalition of user societies is a topic for the better use of limited resources and for the prevention of the underutilization of a reactor [3]. The Internet or virtual reactor laboratories(IRL) [2,15] for education and training are considered as ways to realize these aspects. Thus, when the development of a new low-power research reactor is considered, the provision of linked IRL's may be considered together for national, regional or international networks.

The requirements of training for industry employees should be different from those for university students, and this difference will affect the characteristics of the reactor.

3.2 Safety

Ref. 16 provides the basic requirements for the design, operation, regulation, and decommissioning of a research reactor. For the safety of a low-power research reactor, the followings should be considered in the design and operation [10] together with the requirements in Ref.16.

- The reactor should have a negative power coefficient as large as possible. This should be reminded in the selection of fuel material and reflector material.
- Passive decay heat cooling is recommended.
- Human engineering and cyber security should be well implemented considering that the facility will be accessed by many users.
- The design should minimize the possibility of risk occurrence by the mistakes of users.
- An information service system for the management of the facility should be provided for integrated management and experience feedback for operation and utilization.

4. Remarks

The status and characteristics of a low-power research reactor were reviewed. In addition, some aspects to be considered in the development of a low-power research reactor are proposed. The identification of areas where the stakeholders are of interest for the utilization will be the first step and the safety aspects should be realized using effective and efficient measures.

REFERENCES

[1] IAEA, Research Reactor Data Base, http://nucleus.iaea.org/RRDB/RR/ReactorSearch.aspx
[2] IAEA Nuclear Energy Series, NG-T-6.1, Status and Trends in Nuclear Education, IAEA, Vienna, 2011.
[3] D. Ridikas and et al., New Opportunities for Enhanced RR Utilization through Networks and Coalitions, presented at the Int. Conf. on Research Reactor, Nov. 14-18, 2011, Rabat, Morocco.
[4] IAEA Workshop, Meeting Report of the Small Research Reactor Workshop, Jan. 13-17, 2003, University of the West Indies, Kingston, Jamaica.
[5] IAEA Workshop, Innovative Application of Low Flux Research Reactors, Dec. 6-10, 2010, Kingston, Jamaica.
[6] IAEA Workshop on Innovative Applications of Small Research Reactors, Small Neutron Generators and Isotopic Neutron Sources, April 30 to May 3, 2012. City University of Hong Kong, Kowloon, Hong Kong.
[7] P. Adelfang, IAEA's Cross Cutting Activities on Research Reactors, Int. Conf. on Research Reactor, Nov. 14-18, 2011, Rabat, Morocco.
[8] ANS Position Statement, Research and Training Reactors, revised June 2011.
[9] IAEA TECDOC-1234, Application of Research Reactor, IAEA, Vienna, 1999.
[10] I.C. Lim, Considerations for PECES Low Power MRR, presented at the IAEA Consultancy Meeting on PECES Research Reactor, Oct. 18-20, 2011, Vienna, Austria.
[11] H. Bock and M. Villa, Survey of Research Reactors, http://www.reak.bme.hu/Wigner_Course/WignerManuals/Bratislava/Research_Reactors_I.htm.
[12] E,K. Ronald and et al., SLOWPOKE: A New Low-Cost Laboratory Reactor, Int. J. of Applied Radiation and Isotopes, Vol.24, pp.509-518, 1973.
[13] J. Roglans, Types, Purposes, and Conversion Potential of U.S. Origin Research Reactors, Russian-American Symposium on the Conversion of Research Reactors to Low Enriched Fuel, 8-10 June 2011, Moscow, Russia.
[14] J.E. Matos and R.M. Leli, Feasibility Study of Potential LEU Fuels for a Generic MNSR Reactor, presented at the 2005 RERTR meeting, Nov. 6-10, Boston, Messachusetts, USA, 2005.
[15] A.I. Hawari, Importance of Research Reactors in Human Capacity Building in Nuclear Science and Engineering, presented at the Int. Conf. on Research Reactor, Nov. 14-18, 2011, Rabat, Morocco.
[16] IAEA NS-R-4, Safety of Research Reactor, IAEA, Vienna, 2005.