THE ROLE OF A RESEARCH REACTOR IN THE NATIONAL NUCLEAR ENERGY PROGRAMME IN VIETNAM: PRESENT AND FUTURE

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Abstract

At present, Vietnam has only one research reactor — Dalat Nuclear Research Reactor (DNRR) — with nominal power 500 kW which main purpose is training, radioisotope production, neutron activation analysis and basic research. During operation more than 25 years, the research reactor played a very important role in the development of the nuclear infrastructure and provided numerous products and services. However, due to the limitation of neutron flux level, the out-of-date design of the experimental facilities and the ageing of the reactor facilities, this research reactor cannot meet the increasing user's demands. Therefore, building a new multipurpose research reactor of high power (10 to 20 MW) is essential to increase nuclear potential of the country, to meet the requirements of energy and non-energy related applications, creating staff for nuclear industry. The main role of a new research reactor is to serve the nuclear power development program, promote the application of nuclear science and technology, and training scientific and operational staff for the future nuclear facilities [1].

1. INTRODUCTION

The DNRR has been operated for 25 years and has been utilized as the only neutron source in Vietnam for the purposes of nuclear research and personnel training, neutron activation analysis, and radioisotope production for medical and industrial uses. The capability of the DNRR is much less to support the nuclear power development program and the demands from various application fields. For these reasons, it is necessary to have a new high performance multipurpose research reactor with a sufficient neutron flux and power level as has been proposed in the draft of the national strategy for nuclear power development in Vietnam. It is expected that a new multipurpose research reactor will be put into operation in the time period of 2015 ~ 2020. In practice, it takes a long time to construct a research reactor and also to be utilized as designed by installing experimental facilities.

A nuclear research reactor is mainly used for the generation and utilization of a neutron flux, which has been widely applied to various areas from basic research to industrial and engineering applied researches. Its application fields are still being expanded together with the development of technology. The main role of new high performance multipurpose research reactor is:

— To satisfy the increasing demands for the utilization of the research reactors;
— To support the national nuclear power development program;
— To enhance the development of the science and technology in Vietnam. The nuclear technologies provide essential tools and technical information for the advanced technologies;
— To improve the nuclear technologies and infrastructures including the human resources established through the DNRR;
— To have an opportunity for experiencing the localization of the nuclear power technology.

2. CHARACTERISTICS OF A NEW RESEARCH REACTOR

DNRR has been, and will continue to play an important role as a large national research facility to implement research, development and the demonstration of nuclear energy applications in Vietnam. In order to have a general outlook and better selection of new research reactor, the review of the major characteristics of some currently operational high power research reactors (from 20 MW or more) like HANARO [3], CRCN/PPM-1 [4], ETRR-2 [5], OPAL [6], JRR-3M [7], FRM-II [8], ONRC [9], TRR-II [10] and Offered Russian research reactor [2] was necessary. So basing on this useful information, a design concept of new research reactor of Vietnam was established.

In order to satisfy future demands in Vietnam, a new research reactor is desirable to meet the following basic performance requirements:

- The maximum available thermal neutron fluxes in the irradiation site inside the core and the reflector region should be 2×10^{14} and 3×10^{14} $cm^{-2}s^{-1}$, respectively;
- The neutron flux should be stable for the experiments. The neutron flux variation in an irradiation site due to the loading or unloading samples in other irradiation sites should be less than 5%. Also, the thermal neutron flux at the nose of the beam tube should be stable within a 5% variation regardless of the experimental activities in the other irradiation sites;
- The axial neutron flux gradient at the irradiation site should be within ±20% over a length of 50 cm;
- The average discharge burn up of the fuel assembly should be more than 55% of the initial loading of fissile material, $U^{235;}$
- The reactor operating cycle should be longer than 30 days;
- A reasonable combination of sizes, types and orientations for the irradiation holes and beam tubes is required for various experiments;
- The reactor should have inherent safety characteristics.

Brief description of a new research reactor in Vietnam is presented in Table 1**.** Beside safety requirement, other aspects also should be considered carefully for new research reactor.

TABLE 1. DESIGN CHARACTERISTICS OF A NEW RESEARCH REACTOR

Parameters	Requirements	Reasons
Power (MW)	10 to 20	Enhance utilization abilities
Average thermal neutron flux ($cm^{-2}s^{-1}$)	$2\text{-}4\times10^{14}$	Enhance utilization abilities
Maximum thermal neutron flux ($cm^{-2}s^{-1}$)	$3\text{-}5\times10^{14}$	Enhance utilization abilities
Average thermal neutron flux at reflector ($cm^{-2}s^{-1}$)	$1\text{-}3\times10^{14}$	Enhance utilization abilities
Power and neutron flux peaking factor	As low as possible (axial neutron flux peaking at reflector smaller than 5%)	Safety operation and effect utilization
Core size	Optimize	Enhance utilization abilities. Considering neutron flux and experimental spaces.
Core height (cm)	70-80	Irradiation material with long dimension (NTD)
Reactor type	Open tank and without pressure	Large handling space, storage spent fuel
Fuel	MTR	Popular trading in the world. Easily localization

Fuel burn up and cycle	55% or more, fuel cycle about 30 days or more	Economics and using fuel effectively
Number of FAs in the core	Under 100 Fuel Assemblies	Limit in keeping spent fuel storage. Effectively in using fuel
Control rods position	Upward	Large free space for handling inside reactor core
Reflector	Heavy water or integrated Be, Light water and Heavy water	Better applications. Avoid contamination from the Be and effective when used beam tubes. Second shutdown system by draining heavy water in the reflector
Flow direction through reactor core	Upward	Avoid frequent power outages in the Vietnam.
Coolant and moderator material	Light water	Cheap, economic and easy to maintain. Simple primary cooling systems
Biological shielding	Heavy and light Concrete	Localization, easily replace, safety
Experimental devices		
Irradiation in reactor core	1-3 holes	Designed specifically for radiation research materials and fuels
Silicon Doping	4-6 holes	Different sizes, product diversity, ensuring high quality
Horizontal beam tubes	8-10 channels	Meet the demands for exploitation, researches, irradiations
Vertical channels	25 channels	Meet the needs of isotope productions and neutron activation analysis

3. APPLICATION FIELDS OF A NEW RESEARCH REACTOR

In the early stage of nuclear technology development, research reactors were mainly used for basic researches such as nuclear physics and nuclear chemistry in order to obtain information on the characteristics of the new nuclides generated from the interaction with a neutron. But these days a research reactor as a neutron source is widely used in the areas of engineering, industry, medical and biological engineering and so forth.

Table 2 shows a comparison of the research reactor capacity with different powers, which shows that the DNRR with a 500 kW has limited application ranges and fields. It is necessary to have a new multipurpose research reactor with a higher power level in order to meet the needs demands in the future. It should be put into operation at least before the operation of the first nuclear power plant in Vietnam. In addition to the above-mentioned limitations, the ageing effects of the reactor facilities are also a challenge for the reactor management and operating personnel.

TABLE 2. COMPARISON OF THE RESEARCH REACTOR CAPABILITY ACCORDING TO THE REACTOR POWER

Power	Fuel & material test	Neutron beam research	Neutron Radio-graphy	PGNAA	NAA	RI produc-tion	BNCT	NTD	Training & Education
500 kW	N	VS	VS	VS	S	S	S	N	S
>10 MW	F	F	F	F	F	F	F	F	F

N : no capacity / VS : very small capacity / S : some capacity / F : full capacity

3.1 Neutron beam applications

A neutron beam application is to use the neutrons extracted from the reactor core through beam tubes, which can be applied to the researches on neutron scattering and neutron diffraction, neutron radiography, prompt gamma neutron activation analysis and neutron capture therapy etc.

3.2 Irradiation application

Fuel and material tests by using various types of capsules and fuel test loops are used to examine the burn-up behavior, the mechanical and chemical stability of the fuel elements as well as the fission gas dynamic mechanism under high power steady state and transient conditions.

One of the most important sectors in research reactor utilization is the production of radioisotopes which are used in various ways. The application areas of radioisotopes have been gradually extended together with the development of industry and at present they are used in a variety of fields2.3 Basic research and Training&Education

Neutron Activation Analysis (NAA) is a representative and one of the most sensitive methods of the nuclear analytical techniques used for qualitative and quantitative analysis to determine the trace elements in a variety of complex sample matrices.

Neutron transmutation doping (NTD) is the technology to make a high quality semiconductor by neutron absorption and the transmutation of silicon elements into phosphor elements in a silicon single crystal.

Gemstone coloration is other way of NTD. Gemstones may be irradiated with neutrons to improve their properties in order to increase their demand and monetary value.

3.3 Basic research and training & education

Reactor physics including shielding research is a major discipline in reactor design, operation and safety. Reactor physics experiments and experimental techniques to measure the nuclear parameters in a reactor system are essential for nuclear technology development. A research reactor is the most powerful facility to pursue the areas of concern; flux and power measurement, reactivity coefficient, neutron life-time, time behavior of the reactor, flux perturbation and distribution, etc. These activities will contribute to developing the infrastructure of the nuclear industry.

4. STATUS AND PLAN FOR NEW RESEARCH REACTOR

Government of Vietnam has made efforts in various areas in order to enhance the country to the level of Asia’s developed countries as soon as possible. In the nuclear energy field, a long-term nuclear power development program was proposed. The key objectives of the long-term strategy for the nuclear power development program in Vietnam are summarized as below:

- To develop a nuclear energy source into one of the main energy sources; striving for the first nuclear power plant to be put into operation by 2017~2020 and continuing the construction of other nuclear power plants in the coming years;
- To develop and promote a national nuclear industry step by step in order to localize the nuclear power plant and nuclear fuel technologies and to achieve self-reliance in nuclear technique applications;
- To research, develop and apply nuclear techniques to various fields such as industry, agriculture, medicine, oil industry, hydrology, geology, extractive industry, transportation and civil construction to enhance these fields to a level with that of other Asian countries;
- To develop infrastructures of the techniques and regulations for nuclear safety and radiation protection in accordance with international standards;
- To develop and promote the national potential of nuclear technology to have an advanced level, the same as that of Asia's developed countries for both infrastructures and human resources.

A new research reactor will be launched during 2015 to 2020 in Vietnam by cooperation with Russian Federation and the following activities should be included: Identify a proposed multipurpose research reactor for Vietnam; Assessment of the capability of the Vietnam industry, technology transfers and potential suppliers; Establish a preliminary plan of designing and constructing a new multipurpose research reactor for Vietnam; Assessment of the localization potential.

A preliminary plan for designing and constructing a new multipurpose research reactor should be included in the feasibility study stage. It must describe the scope of the work in detail and the responsible organizations and their functions at the design stage, construction stage and commissioning stage for a new research reactor, and the project period to completion.

Considering the activities at the feasibility study stage, manpower requirements for implementing this stage are proposed as follows:

- Technical personnel who are involved in the assessment and selection of a new research reactor will be required. They will participate in both the national project and the joint study with a foreign technical partner on the identification and evaluation of a proposed conceptual reactor;
- Engineering personnel who will participate in the national project and the joint study with a foreign technical partner, if possible, are needed. They will be involved in the assessment of the capability of the Vietnam industry, technology transfers and potential suppliers;
- Project management personnel are also required. They will join with a foreign partner in order to establish a preliminary plan for the work scope and a detailed implementation plan for a new research reactor project.

5. MAIN RESULTS OF A NATIONAL PROJECT ON NEW RESEARCH REACTOR

A research project [11] on a new research reactor for Vietnam was implemented during the two years (Sept. 2002 – Dec. 2004). In order to meet such objectives, in the framework of the research project, the requirements for research reactor utilization in Vietnam after the years of 2020 have been analyzed, and the design characteristics of the eight typical modern research reactors in the world have been considered and evaluated. Based on the obtained results, the suitable research reactors were chosen for basic design calculation on neutronics and thermo-hydraulics. These topics were analyzed and presented in the five reports as follows:

1) Report No.1: Status of the world's research reactors with the orientation to nuclear power development program. Statistics and classification of research reactors by power levels and utilization purposes were considered. Typical applications of research reactors were analyzed, including development of nuclear fuels, material irradiation studies, development of infrastructure and support to industry, radioisotopes production, neutron activation analysis, transmutation effects, material structure study, neutron radiography, prompt gamma neutron activation analysis, neutron capture therapy, geochronology, and human resource development. Experiences in operation and utilization of the DNRR were also reported in order to identify its important roles as well as its limitations.

2) Report No.2: Effects of research reactor utilization for socio-economic development and nuclear power program in Vietnam. Both power and non-power applications of research reactors were analyzed. For power applications, such as fuels and materials testing, infrastructure development for nuclear power program, the reactor should have a neutron flux high enough, more than $1x10^{14}$ $n.cm^{-2}.s^{-1}$. For non-power applications, one of the most important sectors in research reactors utilization is radioisotopes production for medical and industrial uses. It is expected that, about 3000-5000 Ci per year would be needed for the next ten years and the main radioisotopes are I-131, Mo-99, Tc-99m, P-32, Sm-153, Re-186, Ho-166, Lu-177, Cr-51, Fe-55, Ir-192, Co-60, C-14, S-35, etc. These types and amount can be produced on the reactor with the power of about 10-20 MW_{th} and neutron flux of more than 1×10^{14} $cm^{-2}s^{-1}$. In most developed countries, radioisotopes are supplied from the global marketplace on a commercial basis.

3) Report No.3: Necessity of a high power RR in Vietnam. Applications of research reactor are still being expanded together with the development of technology. In general, in support of nuclear power development, research reactors will play two main roles, namely material testing and infrastructure development. Countries that want to maintain an independent nuclear program localize the manufacture of fuel and equipment, or export power reactor technology will use high power research reactors for the irradiation testing of indigenously fabricated fuel and other reactor components. In a case of Vietnam, a long-term nuclear power development program was proposed. One of the key objectives of this program is to develop a nuclear energy source into one of the main energy sources, striving for the first nuclear power plant, to be put into operation by 2017−2020. For this purpose, together with the localization of nuclear technology, various aspects should be considered, and multipurpose research reactors should be constructed and operated for staff training and sustaining national nuclear expertise.

4) Report No.4: Considerations on the selection of a new research reactor. 62 research reactors with a power of 10 MWt and above were listed and classified by 5 utilization areas, including neutron beam application, material testing, radioisotopes production, safety research and multi-purpose. Nine typical high power research reactors were utilized for design review, including HANARO in Korea (30 MW), CRCN/RPM-1 in Brazil (20 MW), ETRR-2 in Egypt (22 MW), RRR in Australia (20 MW), JRR-3M in Japan (20 MW), FRM-II in Germany (20 MW), ONRC in Thailand (10 MW), TRR-II in Taiwan (20 MW), and Russian offered reactor. For selecting a new research reactor, general characteristics, such as reactor type, reactor coolant and cooling method, reactor moderator and reflector were described; reactor physics,

such as neutron flux, reactivity, burn up and core size were analyzed; reactor fuel, thermal hydraulics, reactor control system and reactor safety were also considered in this report.

5) Report No.5: Siting for a new research reactor. Following the IAEA's guidelines and recommendations, the siting for a nuclear facility as nuclear research reactor and nuclear power plant should be conducted by the three stages: site survey stage, site evaluation stage, and pre-operational stage. In the first stage, three phases should be performed: regional analysis to identify potential sites, screening of potential sites to select candidate sites, and comparison and ranking of candidate sites to obtain the preferred candidate sites. Based on the preliminary results of siting survey and evaluation, 3 preferred candidate sites were shown: 1 site in the North (Hoa Binh province in North-West region), 1 site in Dalat, Lam-Dong province and 1 site in the South (Dong-Nai province).

Considering the national economy growth of Vietnam and the active due service period, a new research reactor should have at least 10 MWth to 20 MWth power in order to meet the increasing user's demands and to correspond to the national nuclear power development after 2010, especially, the first nuclear power plant in Vietnam was proposed by 2017-2020. Activities involved in a new research reactor construction project can be roughly divided by 5 stages, consisted of a pre-feasibility study stage, a feasibility study stage, a design stage, a construction stage, and a commissioning stage.

In order to collect ideas, recommendations and suggestions from different sides, such as scientists, teachers, managers and decision makers, some national meetings and seminars on new research reactor plan have been organized so far.

6. CONCLUSIONS

The DNRR has been safely operated and effectively utilized for more than 25 years. It has been, and will continue to be played an important role to the development and delivery of benefits of nuclear science and technology in Vietnam. Because of many limited factors in neutron flux, experimental facilities, etc …the DNRR has been applied to few areas among the various research reactor application fields. So the new multipurpose and high power research reactor should be put into operation before 2020 to support for the nuclear power development program and non-power utilizations in the future of the country.

Many stages and problems in construction a new research reactor also need to be considered carefully such as assessment of the type of reactor, abilities of localization potential, establishment an implement plan and schedule, manpower requirements and international cooperation.

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