Feasibility study to develop BNCT facility at the Indonesian research reactor

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Abstract. Survey to the Indonesian research reactors and its supporting facilities have been done in order to check possibility to install BNCT facility. Oncologists from several hospitals have been informing about the BNCT treatment for tumours and they give a positive response to support utilisation of the BNCT facility. Several aspects required to support the BNCT treatment have also been identified and related activities on that matter soon will be initiated. The interim result in our survey indicated that utilisation of the 30 MW Multipurpose reactor would not be possible from technical point of view. Further study will be concentrated to the TRIGA reactor and an epithermal neutron beam facility at the thermal column of this reactor will be designed for further work.

INTRODUCTION

Three research reactors are available in Indonesia, operated by National Nuclear Energy Agency of the Republic of Indonesia (BATAN). Those three reactors are: TRIGA Bandung reactor 2 MW located at Bandung, TRIGA Kartini reactor 250 kW at Yogyakarta and Multipurpose Research Reactor 30 MW at Serpong. Using those three reactors, especially Triga Bandung and Multipurpose Research Reactor RSG-GAS, radioisotope for nuclear medicine has been produced and then distributed to the hospital. Up to know 19 hospitals in Indonesia have been facilitated with nuclear medicine unit.

Support of BATAN to develop and to enhance nuclear medicine in Indonesia have got a good respond by hospital, especially hospital at the near by research center operated research reactor. Some hospitals are also used as a teaching hospital of the university in those cities. Based on this condition a good relationship has been settled between BATAN, hospital and Faculty of Medicine of that University.

In the last two years, BATAN has considered that utilisation of the research reactor should be improved. One of the ideas is development of the BNCT facility at one of the research reactors. In the other hand oncologist reported that incidence for cancerous tumours and certain brain tumours in Indonesia is high enough. For example data from Sardjito Hospital in Yogyakarta stated 30 brain tumour patients in 1998 have been treated using combination of ***surgery***, and photon irradiation and the result were unsatisfied.

Feasibility study to develop BNCT at the Indonesian Research Reactor is being done. With support of the Japan Atomic Industrial Forum (JAIF) one Japanese expert on BNCT facility has been assigned to support feasibility study to develop BNCT at the RSG-GAS reactor or at the TRIGA Kartini reactor. With support of the Japan Atomic Energy Research Institute (JAERI) author has a chance to visit BNCT facility in Japan and also to gather latest information on the BNCT technology, especially on the preparation of the reactor and beam design to facilitate BNCT treatment facility.

In regard of the purpose, author as a person who is responsible for feasibility study of the BNCT in the Indonesian Research Reactor is willing to attend on the IAEA TCM on current issue related to Neutron Capture Therapy to gather latest information on this technology

1. RESEARCH REACTORS IN INDONESIA

Three research reactors are available in Indonesia, those reactors are: TRIGA type reactor Bandung, Kartini (TRIGA) reactor Yogyakarta, and Multipurpose Research Reactor (MTR-type) RSG-GAS located in Serpong Nuclear Research Center[1]. Further detail description and also its status are described below.

TRIGA reactor in Bandung

TRIGA reactor Bandung has been operated since 1964. On the early period of its operation the reactor has a nominal power of 250 kW. Last 1971, the reactor was then upgraded to 1000 kW with replacement of the reactor core and its fuel elements; instrumentation and other related process system equipment. The TRIGA Bandung reactor has utilized for radioisotope production purposes, neutron beam experiment and also training for reactor operator; as well as doing some reactor physics experimental activities. This reactor has 4 beam tubes, 3 radial and 1 tangential tube, thermal column and thermalizing column.

Since at the beginning of the reactor project being initiated, close cooperation between BATAN and University (Bandung Institute of Technology and Padjadjaran University) has been settled. Base on that situation, the reactor has been also used as a versatile tool by students as well as researcher from the university together with BATAN's staff. It can be stated also that Research and Development (R & D) on nuclear technology in Indonesia has been started using this reactor.

Several types of radioisotopes have been produced using this reactor. Radioisotope for medical purposes, such as: ^{131}I and $^{99}Mo/^{99m}Tc$. Other radioisotope has been produced either for hydrology (^{82}Br) or R & D on agriculture; ^{32}P.

This reactor has a laboratory for NAA and equipped with a nuclear counting system as well as personnel to perform neutron flux measurement and neutron dosimetry. A big hospital with nuclear medicine facility is available around 5 km from the reactor site. This hospital is also used as a teaching hospital by faculty of medicine, Padjadjaran University.

Up to 1990, medical radioisotope as well as radioisotope for other purposes in Indonesia were fulfilled by this reactor. When the new reactor RSG-GAS, 30 MW and the radioisotope laboratory in Serpong become in operation, radioisotope required for medical as well as for industry and other purposes where then fulfill by this new reactor. Since then the TRIGA reactor in Bandung is mainly used to perform R & D on new radioisotope and also this reactor is used as a backup when the RSG-GAS reactor in the shut down period. Nowadays, reactor TRIGA in Bandung is being upgraded to be operated for 2 MW power level. The activities are being done and it expected will be finalized within next 2 year.

Kartini reactor in Yogyakarta

Kartini research reactor is a 100 kW TRIGA operated since 1979 in Yogyakarta. Modification on the instrumentation system has done last 1997 and the reactor system has

also modified to improve reactor operation at 250 kW power level. This reactor is equipped with in-core as well as in reflector irradiation facilities. The irradiation facilities are equipped also with rabbit system and also gamma spectrometry system as well as delayed neutron-counting system. So that this reactor can be used to perform NAA (Neutron Activation Analysis) and also U-Th analysis (using delay neutron counting technique) from the ore. This reactor has 4 beam tubes, these tubes is equipped with γ and neutron radiography and sub-critical assembly. The thermal column and thermalizing column are available in the reactor, see Figures 1 & 2.

The Kartini reactor is operated by Yogyakarta Nuclear Research Center, which is very closed relationship with Gadjah Mada University. Based on this situation, the Kartini reactor is used as a training facility for student from the Gadjah Mada University.

Several hospitals, both government as well as private are located near by this reactor facility in the distance less then 10-km. Faculty of Medicine of the Gadjah Mada University uses the government hospital also as a teaching hospital.

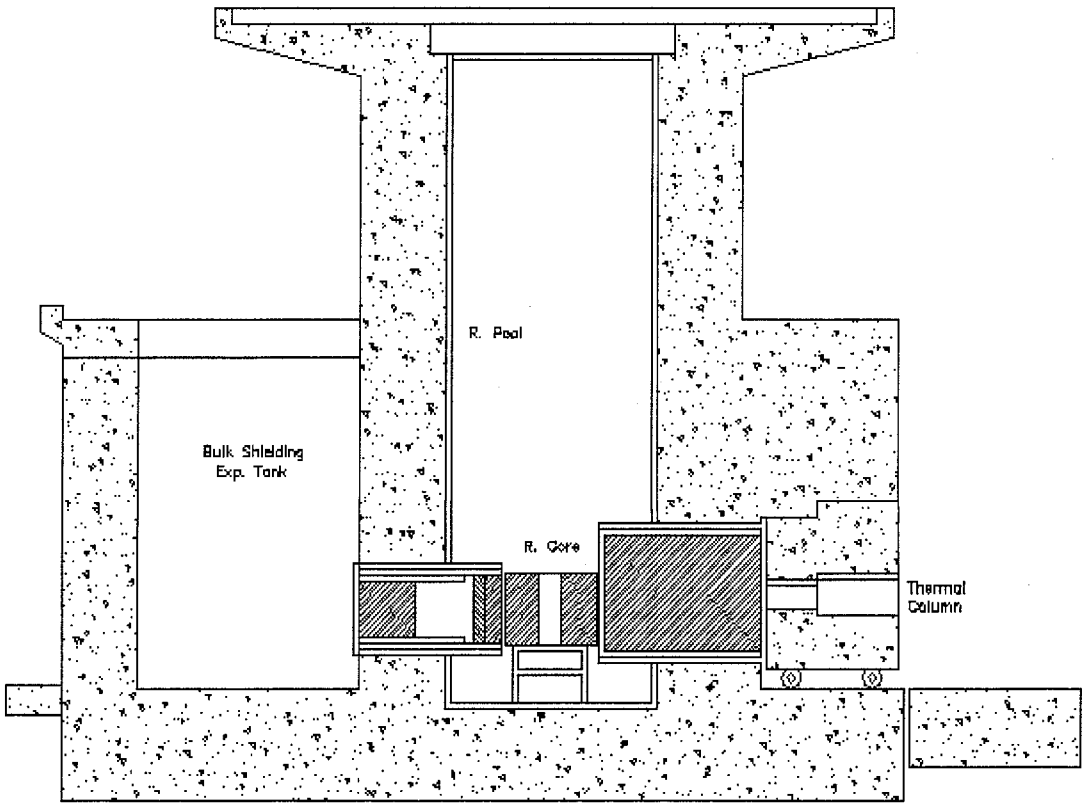

FIG. 1. Vertical cross-section of the TRIGA Kartini reactor.

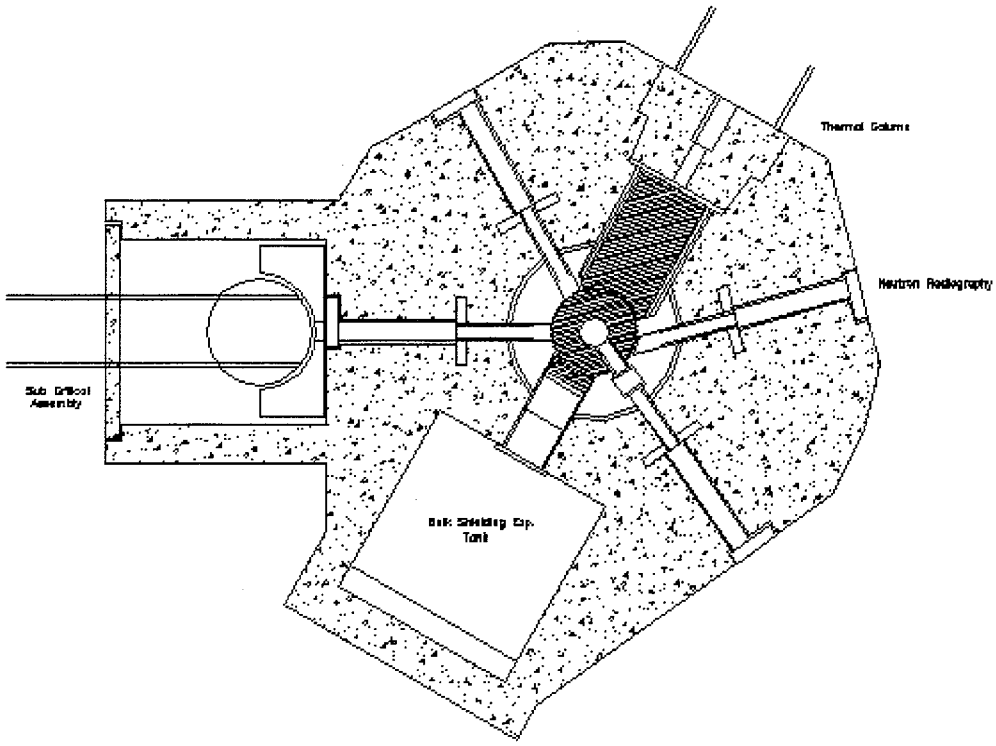

FIG. 2. Horizontal cross-section of the TRIGA Kartini reactor.

Multipurpose research reactor RSG-GAS

The RSG-GAS reactor is located in Serpong Research Center, it has nominal power 30 MW. The RSG-GAS reactor is a plate type/MTR type reactor using LEU fuel in form of U_3O_8-Al. This reactor is equipped with irradiation facility as well as equipment for neutron beam experimental purposes, see Figure 3.

This reactor was officially inaugurated on August 1987 and reactor utilization for radioisotope production was started on December 1990. Up to know this reactor produced the entire radioisotope used in Indonesia, either for medical purposes as well as for industrial purposes. Some of the radioisotopes produced from this reactor are also exported to foreign country. The reactor equipped with 6 beam tubes, one of this up to know is still unused. The other beam tubes used for radioisotope production (^{125}I), and neutron beam experiments purposes, i.e. neutron radiography, powder diffractometer, triple axis spectrometer, neutron guide tube, etc.

This reactor is also has a facility for fuel element irradiation under high pressure and temperature condition as occurred in the NPP. This reactor has equipped with a power ramping facility, a facility to stimulate power ramping on the BWR or PWR fuel element under irradiation condition.

This reactor is located in Serpong, a suburb of Jakarta for about 35-km in Southwest direction. Several big hospitals either private or government own are available in Jakarta, however due to traffic condition in near by Jakarta, at least one and half hour is required to go from the nearest hospital in Jakarta to the reactor facility in Serpong.

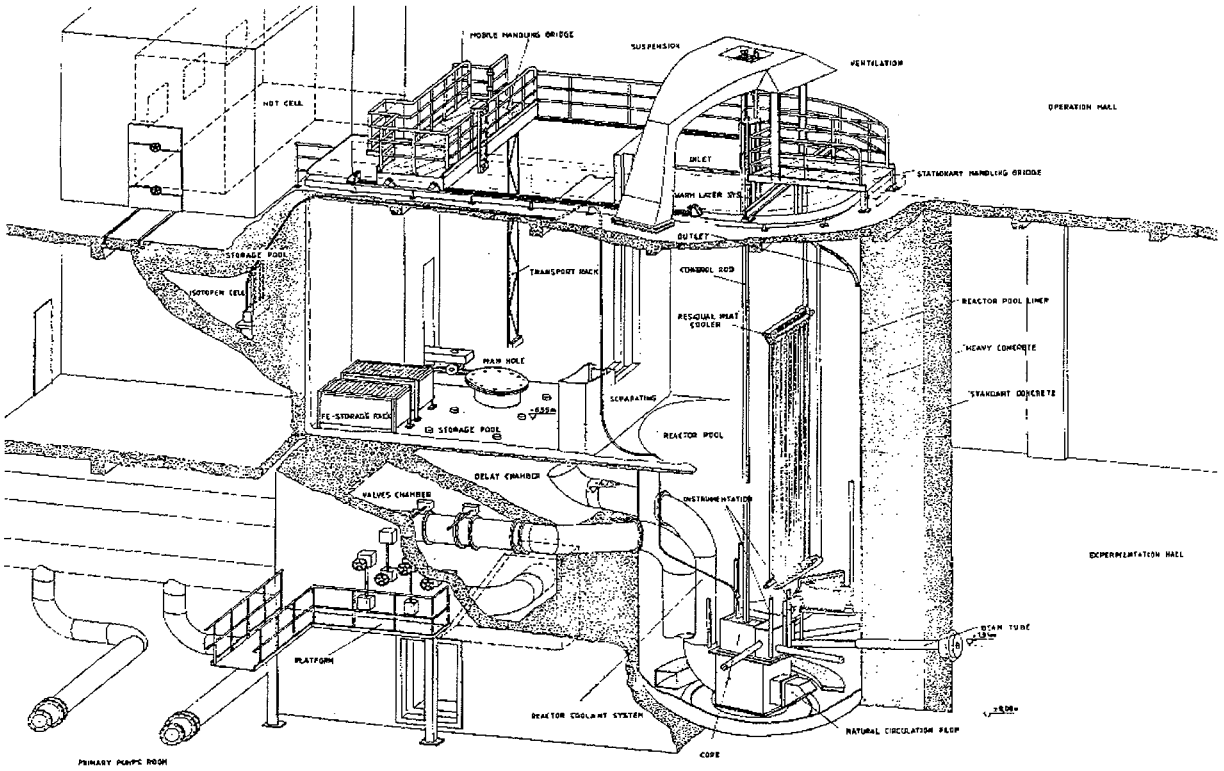

FIG. 3. Isometric drawing of the RSG-GAS reactor.

Survey to the Indonesian research reactor for the BNCT treatment facility have done with the following criteria:

(a) Neutron flux requirement: neutron flux might be used at the front of beam tube or other facility should be around 10^8 — 10^9 n/cm^2.s for thermal or epithermal [2,3]. It was considered also possibilities to modify such of beam-tubes arrangement if it would be needed to reach that requirement. It was considered also volume of the beam and available space in front of beam tube to allow activities for BNCT treatment.

(b) Reactor utilization program: Since the BNCT treatment requires preparation in the reactor area/ room, neutron as well as gamma beam shutter is absolutely needed, other wise reactor should be started up and shut down to perform this treatment or single purpose only.

(c) Supporting facility: The most important supporting facility is neutron flux measuring laboratory and boron concentration measurement facility. All of the reactor facilities have a laboratory to perform neutron flux as well as neutron spectrum measurement. The available equipment to measure boron concentration in the tissue as well as in the blood is ICP-MS, and this equipment is available in Serpong facility.

(d) Potential users of the BNCT/hospital: Positive response of the medical staff in the hospital, their expertise as well as facility available on that hospital is considered as a supporting items to decide utilization of the reactor for BNCT.

With a support of JAIF, a BNCT expert of JAERI has visited Indonesia and spent around one week at the RSG-GAS reactor in Serpong beginning of this year. He has performed intensive discussion with the Indonesian reactor engineered and he explains basic

requirement for the BNCT facility. He has visited also TRIGA reactor in Yogyakarta and performed technical discussion with reactor engineers and medical doctor/oncologist of the Sardjito hospital and Faculty of Medicine, Gadjah Mada University. With support from JAERI, Japan, author has spent 2 weeks in JAERI facility to gather further detail information regarding BNCT technology, and he has also visited several institutions operated these facilities. During his visit to Japan, discussions with specialist expert on neutron beam design as well reactor engineers have been done in order to finalise decision on which reactor the BNCT facility will be installed.

Result on this survey indicated that the RSG-GAS reactor is not suitable to perform BNCT treatment due to some reasons:

(a) Neutron beam as well as volume of the neutron beam available in the front of beam tube is only 10^7 and it is not sufficient [4]. Beam-tube modification is very difficult and also not possible since utilization program of the reactor.

(b) Neutron and gamma beam shutter is required because other wise reactor utilization program will be disturbed by BNCT treatment. However, construction of the beam shutter in this room/hall is not possible since limitation on available space on this area as well as bearing capacity of that floor is limited.

(c) Transportation of the patient being treated from hospital to the reactor facility is rather difficult since arrangement of the reactor building, and also traffic from Jakarta to the reactor site vice versa are not comfortable.

Since the RSG-GAS reactor is not suitable for the BNCT facility, other two TRIGA reactors are considered to be used for that purposes. Further activity on preparation of the beam design for BNCT will be concentrated to the TRIGA reactor. Using TRIGA reactor, BNCT facility should be installed in front of the thermal column. Availability of the supporting facility as well as a good response of oncologist and other medical staff of the Sardjito hospital and Gadjah Mada University to the BNCT program is indicating that utilization of TRIGA reactor in Yogyakarta will be feasible.

2. FURTHER STEP ON BNCT ACTIVITY IN INDONESIA

The BNCT facility in Indonesia is planned in operation within next 5 years from now on. Based on the literature survey referring to the other facilities now is available [2,3,5,6] or being available in the near future [7], epithermal neutron beam is more preferable rather than thermal neutron beam. To follow on the tendency, BNCT facility for the Indonesian TRIGA reactor is planned to use epithermal neutron beam.

Since the BNCT program has started, several activities now were identified and also initiated. The main activities can be described as follows:

Beam design

The thermal column of TRIGA reactor will be modified to produce epithermal neutron beam required for the BNCT facility. Material in the thermal column will be changed in order to get epithermal neutron beam. As the first step, the reactor physics calculation using Monte Carlo code MCNP is initiated. To get a better result and also to speed up the calculation process, shifter material or moderator and also photon g-shield have used in the Finnish reactor [8] will be considered. Calculation model as described by Matsumoto [9,10] will be

applied on this work. Completion of this work will be followed with the next step to perform engineering design to prepare basic and detail design. Preparation of the reactor physics calculation as well as engineering activities of the neutron beam design is planned for two years. This activity will be followed by construction, testing and commissioning of the equipment, including also phantom measurement.

Neutron dosimetry and treatment planning

At the reactor facility, neutron flux and spectrum measurements have done using foil and wire activation detectors. Laboratory with nuclear counting system is available, included also sample changer to perform multiple sample analysis. Neutron flux measurement using SPND is also used in the experimental facility. Since manpower to perform these activities is also available, the most important activity to be done in the field of neutron dosimetry is improvement on accuracy and to speed up the measurement result. The other aspect of dosimetry for BNCT as described by Watkin [11] will be considered and prepared. Dose treatment planning can be done through calculation process and it will be checked or verified using measurement.

B concentration measurement

B concentration in tissue and blood can be measured using PGAA and ICP-MS/AES. Up to know PGAA system is still under designed, although this activity previously is planned to detect other light element in the air pollutant. It is expected that within 5 years from now, the equipment is ready and well-trained personnel are available to determine B concentration in tissue as used in other facility [12]. The ICP-MS is available and also well-trained personnel are ready to perform light element identification and measurement.

Radiobiology and pre-clinical experiment

Radiobiology and pre-clinical experiment for animal will be continued, as previously done using TRIGA reactor in Bandung. This experiment should be done in co-operation with medical doctor or oncologist to get better result.

3. CONCLUSIONS

Feasibility study to develop BNCT facility at the Indonesian reactor has been done and a good response from the potential user has considered. Results of this study can be found as follows:

- BNCT study in Indonesia is being started and it is planned that the facility will be available within next 5 years.
- TRIGA reactor will be used instead of multipurpose RSG-GAS, epithermal neutron beam will be chosen rather than thermal neutron.
- Neutron beam design activity is being started with reactor physics calculation and it will be followed with an engineering activity.
- Other activities on neutron dosimetry, boron concentration measurement, and other aspects are also being initiated.

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