Implementation of TRR-1/M1 for Thailand's Nuclear Engineering Program

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Abstract

A course on the experiments with TRR-1/M1 (Thailand's Research Reactor 1, modification 1) was planned. This was to be a required course for Thai graduate students who would be pursuing a degree in nuclear engineering. With the limitation imposed by the condition of the TRR-1/M1, together with the available time and resources, six different experiments were to be conducted in order to familiarize the students with many necessary nuclear engineering concepts. At this beginning stage, the experiments to be conducted were (1) the approaching of the criticality for TRR-1/M1, (2) the control rod calibration, (3) the measurement of the thermal neutron fluxes, (4) the measurement of the fast neutron fluxes, (5) the profiling of the axial fluxes and (6) the calibration of the thermal power.

In addition, the students registered for this course must attend a preliminary lecture provided by the operators of TRR-1/M1 in order to orientate themselves with the guideline and procedure required for their own safety and for the safe operation of TRR-1/M1.

Introduction

Nuclear science and technology were first introduced into Thailand with the implementation of "Atoms for Peace" program as announced by Eisenhower, the former US president. When the law "Atomic Energy for Peace Act" became effective in 1961, OAEP (Office of Atomic Energy for Peace)[1] was established as the government agency in which to implement, control and regulate all the activities involving the radiation and all nuclear applications in Thailand under the policy and guidance given by the Atomic Energy for Peace Commission. The operation of a research nuclear reactor was then the responsibility of OAEP. Due to the government restructuring in 2002, OAEP was renamed as OAP (Office of Atoms for Peace) but it still retained its original function. In order to separate the roles of a regulator and an operator, TINT (Thailand Institute of Nuclear Technology)[2] was founded by a government decree in 2006 and was given the task of conducting the research and the development regarding radiation and nuclear activities. OAP, on the other hand, had since assumed the responsibility of the regulatory body. Due to the restructuring, the operation of Thailand's nuclear research reactor was then under the authority of TINT.

Currently, Thailand employs only one nuclear research reactor; TRR-1/M1 (Thailand's Research Reactor 1, modification 1). TRR-1/M1 is a TRIGA Mark III typed 2-megawatt nuclear research reactor built by General Atomics[3]. Originally, the plate typed fuel with highly enriched uranium (HEU) and U3O8-Al cladding was used with the light water as both the moderator and the coolant. The reactor went critical on 27th October 1962 at the power of 1 MW. In 1975, to conform to the Treaty of Non-Proliferation of Nuclear Weapon, the reactor was temporarily shutdown for its first modification (thus, the suffix /M1 in its title). The reactor core and the control system were disassembled and replaced. The new core is of hexagonal shaped with the uranium enriched at 20% in ^{235}U (LEU) and ZrH alloy as the fuel. This modified reactor reached criticality on 7th November 1977.

From the first day of its operation, TRR-1/M1 has been used mainly for producing the radioactive materials for the medical purpose and for conducting research and analysis regarding neutron irradiation. Even after so many decades, TRR-1/M1 is still the most valuable tools for the development of nuclear technology in the country. However, since TRR-1/M1 is aging, the need for the new research reactor has become prominent and the construction of a new one is being expected.

In participating with the possibility of introducing the nuclear power plant into the country, the Department of Nuclear Technology[4] was established in 1975 at Chulalongkorn University, Bangkok, Thailand. This was aimed to prepare the personnel and to develop the knowledge necessary for the operation and the maintenance of the plant. Due to the political and the economical reasons at various different occasions, the implementation of the nuclear power plant was never materialized. Consequentially, the department had mostly concern itself with the development in the field of the radiation.

Recently, with the renewed interest in nuclear power, the department has begun updating its curriculum on the nuclear engineering program. Together with the founding of TINT and the expectation of the new research reactor, TINT and the Department of Nuclear Technology have agreed to implement TRR-1/M1 for the purpose of nuclear engineering education. This cooperation is expected to provide a good hand-on practice to the graduate students regarding the reactor theory and the reactor experiments. At the same time, the operators will have the opportunity to improve their skills in managing the reactor and their skills in instructing and in communication. Most of all, this cooperation shall put the aging TRR-1/M1 into good use as an educational tool while the new research reactor will subsume the role of producing the radioactive materials and of conducting the research and the analysis.

Present Condition of TRR-1/M1

After the modification on TRR-1/M1 which had begun in 1975 and its re-criticality in 1977, 14 core loadings have been implemented over the period of 30 years and the 15th loading is scheduled to be implemented at the end of April or by early May 2007. In general, these loadings are some what similar in pattern. For example, Figure 1, Figure 2 and Figure 3 respectively show the outline of TRR-1/M1, its 14th core loading and the structure of the fuel element[5].

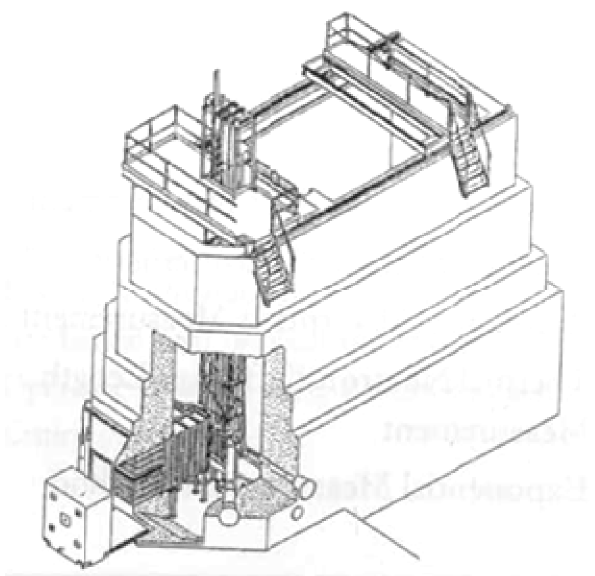

Figure 1. The Outline of TRR-1/M1

Figure 2. 14th Core Loading of TRR-1/M1

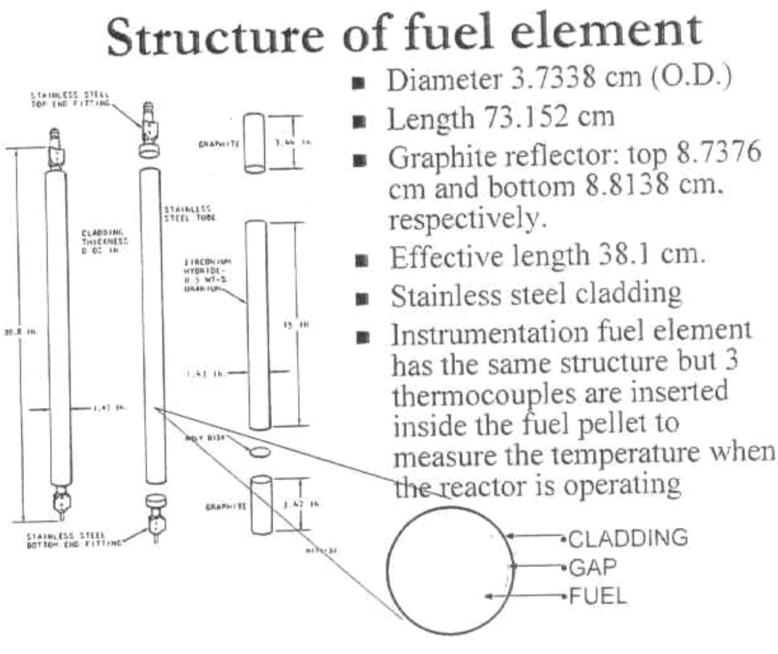

Figure 3. Structure of Fuel Element

TRR-1/M1 is an open pool type TRIGA Mark III research reactor. According to its original specification, TRR-1/M1 has the maximum steady state power of 2 MW but can achieve the maximum power of 2000 MW when it is operated in pulsing mode. Due to its present condition, however, TRR-1/M1 is now only run with the maximum power of 1 MW and is not allowed to run in pulsing mode. TRR-1/M1 uses the 20% lowly enriched uranium and is cooled and moderated by the light water. TRR-1/M1 also employs 5 control rods for controlling the fission rate and for shutting down.

Proposed Experiments with TRR-1/M1

With the aging problem of TRR-1/M1, the obsolete equipments for control and measurement, together with the rather low positive reactivity associated with the fuel available for TRR-1/M1 and the limited budget allotted for the program, the experiments that are feasible with TRR-1/M1 must be considered. As suggested by Dr.Nobuaki Onishi, the researcher from NSRA (Nuclear Safety Research Association) who had an extensive experience with TRR-1/M1 and was visiting the Department of Nuclear Technology by the support of MEXT (Ministry of Education, Culture, Sports, Science and Technology, Japan) during 2004-2005, three categories of experiments were devised.

1. Category 1: The experiments in this category are those which can be readily implemented and conducted with TRR-1/M1 without or with only slightly modification. The proposed experiments in this category are (1) the criticality approach, (2) the control rod calibration, (3) the thermal neutron fluxes measurement and (4) the thermal power calibration.
2. Category 2: This is the category for the experiments which some new instruments must be acquired and minor modification on TRR-1/M1 may be needed. The possible experiments in this category are (1) the measurement of the fast neutron fluxes, (2) the measurement of the reactivity coefficients and (3) the measurement of various kinetic parameters.
3. Category 3: The experiments in this category need substantial investment in new equipments and may require substantial modification on TRR-1/M1. The measurement on the resonance absorption and the diffusion length, together with the experiments regarding the pulsing mode and any rapid transients are considered as being in this category.

From these 3 categories, 6 experiments are considered feasible based on the condition of TRR-1/M1 and the available resources. These experiments are as given in the following list.

1. The approaching of the criticality for TRR-1/M1

   This experiment is actually the standard practice for training the operators for TRR-1/M1. Therefore, the operators are familiar with the procedure and should be able to conduct this experiment with minimal adjustment. As for the students, they shall learn the process in which the reactor is started up and how to the control the criticality of a reactor. The relation and the adaptation of the kinetic theory with the actual measurement of the reactor period are also emphasized.
2. The control rod calibration

   This is the procedure normally practiced together with the core loading of TRR-1/M1. For the students, they shall learn how to measure the reactivity of a control rod and how it affects the criticality of a reactor.
3. The measurement of the thermal neutron fluxes

   This experiment is intended to demonstrate to the students how the thermal neutron fluxes can be measured with the method of foil activation.
4. The measurement of the fast neutron fluxes

   This experiment is intended to demonstrate to the students how the fast neutron fluxes are measured with the threshold detectors.
5. The profiling of the axial fluxes

This experiment is designed to relate the neutron diffusion theory to its actual application in the calculation of the neutron fluxes.

6. The calibration of the thermal power

   This experiment is designed to calculate the power density at the different location of the research reactor based on the calorimetric method. The result from the calibration shall demonstrate to the students the relation between the neutron fluxes and the power densities.

For these experiments, in addition to the operation manual of the TRIGA Mark III reactor as supplied by GA, the procedures for the experiments are written based on the experiment manuals prepared by the University of Wisconsin-Madison[6], the Pennsylvania State University[7] and BHABHA Atomic Research Center[8] to be used respectively with their research reactors.

Course Implementation

The schedule for the experiments is set to begin in June 2007 with the starting of the first semester by the university. Since this is the first offering of the course, the graduate students under the mutual program between TINT and the Department of Nuclear Technology will be the first group of the students to attend this course. As these students are actually the operators of the reactor or the researchers already familiar with the reactor, they should have little problem regarding conducting the experiments. Their inputs on the experiment manual, the preparation of the experiments, the discussion and analysis before and after the experiments and on the preparation of the report on each experiment will be most essential.

The course on the experiments is planned to offer once for every academic year. The students required to attend the course are those who will be pursuing the master/doctoral degree in nuclear engineering. The students who work for the master/doctoral degree in nuclear technology are not required to take the course. They are welcome to take the course, however, as long as the number of the students in the course does not exceed the set maximum. In any case, the priority for registering for the course will be first given to the students for the degree in nuclear engineering.

At this stage, the maximum number of students that can take the course on the experiments with the research reactor is expected to be limited at no more than 10. Since the Department of Nuclear Technology now only offers the graduate degree, such number of students does not pose any problem. However, if and when the program for the undergraduate students in nuclear engineering is approved by the university, more students may be taking the course. In such case, an offering in each semester may be necessary.

As is the case with the training of the operators of the research reactor, the students who are taking this course must have a good understanding regarding the safety culture and the safe practice for working with the reactor, together with the adequate knowledge on the radiation protection. For this purpose, the students are required to attend a short preliminary course given by the operators of the reactor before they will be allowed to participate with the experiments. The preliminary course to be given by the operators will cover the safety guideline for working with the reactor and for working in the area exposed to the radiation, the procedure for operating the reactor and the emergency plan in case of an accident.

The grading for the students will be based on their attendances, their adherences to the safety practice and to the procedure set for each experiment and on the quality of their reports to be submitted after each experiment is concluded.

Summary

The cooperation between TINT and the Department of Nuclear Technology on implementing the research reactor TRR-1/M1 for a laboratory course in nuclear engineering education has been initiated. The course is planned to begin in June 2007 with the graduate students from TINT and OAP under the mutual program with the Department of Nuclear Technology as the first of the students to attend this course. Their inputs regarding the course will be used to evaluate and improve the course's content and the related materials.

Six experiments were planned for this course; (1) the approaching of the criticality for TRR-1/M1, (2) the control rod calibration, (3) the measurement of the thermal neutron fluxes, (4) the measurement of the fast neutron fluxes, (5) the profiling of the axial fluxes and (6) the calibration of the thermal power. These were decided based on the availability and the condition of the reactor, together with the allotted budget and resources. As the nuclear engineering degree offered by the department is now for the graduate level, a limited number of students are expected. Therefore, only once course per academic year is considered. However, if the under graduate degree is approved by the university, the higher number of students to attend the course is possible. In such case, the second offering may be needed.

More advance experiments had also been considered. However, it was decided that implementing them at this stage might not be feasible. When the new research reactor becomes available and/or TRR-1/M1 is thoroughly refurbished and upgraded, these advanced experiments will again be evaluated for implementation.

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