NTHU Roadmap Review Report (draft)

Center of Reactors Laboratory

The major task of the Nuclear Reactors Laboratory is to operate and maintain the Tsing Hua Open-pool Reactor (THOR) and to ensure uninterrupted services for neutron irradiation, personnel training, and radioisotope production. To make these services constantly available, this laboratory offers irradiation facilities, peripheral research equipment, and supporting staff to those who are interested in nuclear related activities. In addition to running the THOR, neutron activation analysis, neutron radiography, and ageing management for nuclear reactors are also major research activities in this laboratory.

1. Current Status

THOR is a 2 MW, light water moderated and cooled reactor of the TRIGA conversion type (as shown in figure 1). The average thermal neutron flux in the core is about 1×10^{13} n/cm^2/sec at 1 MW. It is now the only nuclear research reactor that can provide stable and continuous bulk quantity of neutrons in Taiwan.

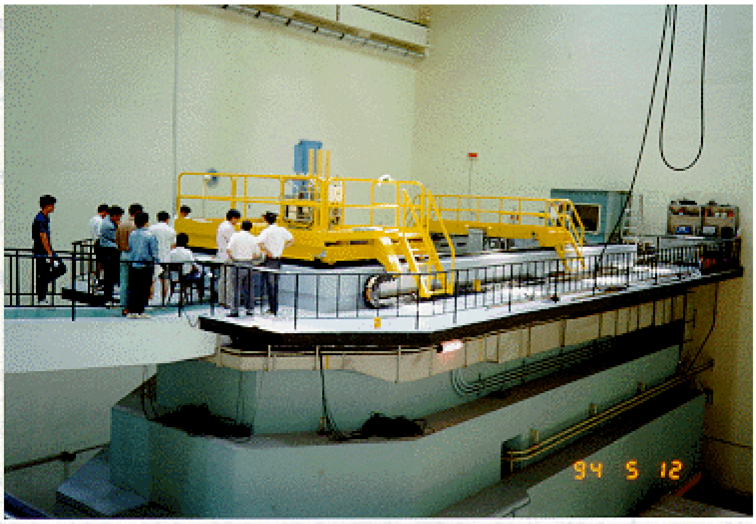

Figure 1. The reactor hall of the Tsing Hua Open-pool Reactor (THOR)

✧ Strength

a. The license for THOR had been renewed to 2011.

b. Thermal column had been remodeled for BNCT purpose in 2004.

c. The only reactor that can provide a stable, continuous, and quantity of neutrons.

✧ Weakness

a. Four operators will retire within the next 5 years.

b. Recent development and improvement in mass analysis gradually take the place of neutron activation analysis (NAA) conducted in research reactors.

c. Experimental hardware remains expensive while the operation budget is severely declining.

✧ Promising areas

a.	Boron Neutron capture Therapy (BNCT)	40%
b.	Joint to the international neutron beam-line project (J-PARC)	30%
c.	Others (RI production, NAA, radiography, ageing management.)	30%

✧ National standing

There are two nuclear research reactors in Taiwan: the THOR at Tsing-Hua University and the ZPRL at INER. However, ZPRL will be shutdown in 2006, and THOR will be the only one that can provide a stable and continuous bulk quantity of neutrons.

✧ International standing

Currently, there are 274 nuclear research reactors still in operation in the world. Thirty of them are operated at 1~2 MW. The neutron flux vs. the reactor thermal power is shown in figure 2.

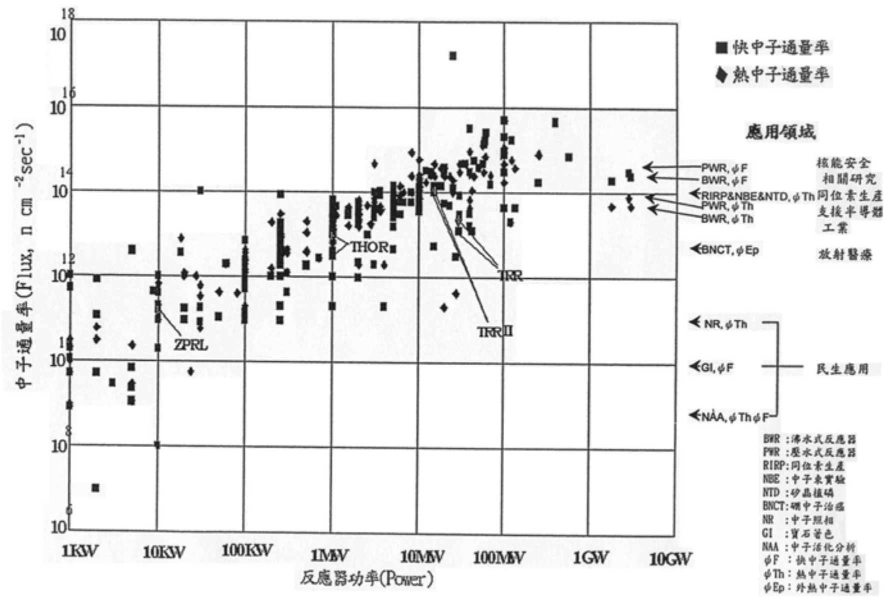

Figure 2. The neutron flux vs. the reactor power of the research reactor in the world

The applications for a research reactor with medium neutron flux (φ_{th} ~10^{13} n/cm^2/sec) include neutron scattering, neutron radiography, neutron activation analysis, and neutron irradiation (e.g. RI production or BNCT). The BNCT has been treated as a potential method for curing brain tumor and other cancers. In order to initiate the BNCT research and provide a suitable facility in Taiwan, THOR was shut down for renovation from January of 2003 to July of 2004 (as shown in figure 3). This program is finacially supported by National Science Council. The working groups include National Tsing-Hua University (NTHU), Taipei Veterans General Hospital (TVGH), National Yang-Ming University (NYMU), and National Chung-Hsing University (NCHU). As listed in Table 1, THOR will be the 7^{th} BNCT facility with an epithermal neutron beam in the world. In comparison with the beam quality of THOR with the other BNCT facilities in the world, THOR does have the opportunity to be a qualified facility for BNCT purpose.

Aside from the BNCT application, it is a unique opportunity for this laboratory to participate in ageing management for nuclear reactors since there is an aged reactor here at NTHU. For the past six to seven years, we have conducted more than five research projects funded by Taiwan Power Company (TPC), all related to improving the structural integrity of boiling water reactors. In fact, an innovative corrosion mitigation measure was proposed and developed in this laboratory and has attracted attention in the world nuclear industry. The ageing management issue continues to be a major concern of TPC. More research funding in this area is expected and expertise from this laboratory will therefore be appreciated.

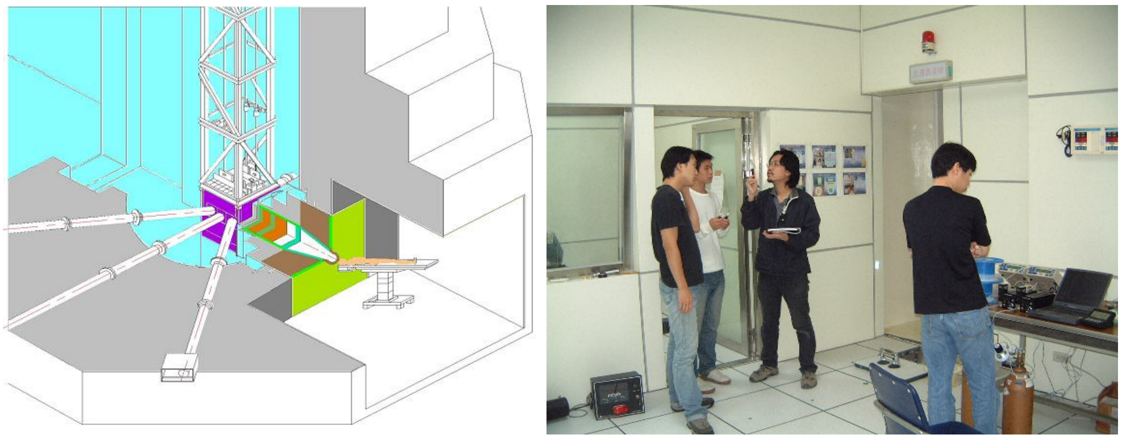

Figure 3. The overview of the BNCT irradiation room and experimental area

2. Goals in 3-5 years

The main goal for this laboratory in the next few years is to promote the service of THOR for BNCT purpose and to help the BNCT program step into clinical trials smoothly. Leading the applications for clinical trials is the cell and animal tests this year. Dr. Lui, the vice president of TVGH, has promised to conduct the hepatoma clinical trials. In the meantime, Dr. Chou, RI laboratory head of NTHU, will prepare the boron containing drugs for liver cancer remedy. THOR can fully support irradiation of more than 100 patients per year. The BNCT international collaboration project will also be initiated this year. Dr. Ray Moss (Technical coordination and management of BNCT clinical trials at HFR of the European) already expressed his willingness to visit THOR for information exchange. Dr. John Gueulette (professor of University Catholique de Louvain, Belgium) will come to this site at the beginning of 2005 for mice irradiation experiments. Other BNCT groups will also come here for cross-checking the beam quality and treating plan layout.

Other than the BNCT program, we wish to continue the well-established research work in ageing management for nuclear reactors. Through collaboration with Institute of Nuclear Energy Research and Material Research Laboratory of ITRI, we intend to help the three domestic nuclear power plants to achieve the goal of no hazard to the public even under extended periods of operation. The ageing management program has been set as a major task for each nuclear power plant at TPC for the next six years. This laboratory will certainly be involved in this program.

3. Action plans to achieve the goals (prioritized)

BNCT

a. Implementation of the dos on-line monitoring system by 2005.

b. National collaboration for BNCT in vitro/vivo study (ex. VGHUST proposal)

c. International collaboration for beam quality cross-checking and treating plan layout.

d. Implementation of irradiation protocol and quality assurance by 2007.

e. Heading for clinical trials in 2007.

Ageing Management

a. Maintaining close contact with TPC headquarters and plant personnel.

b. Collecting relevant and updated information in the literature and through international fellow scientists.

4. Resources needed (prioritized)

Although surgeons will take charge in the BNCT clinical trials, the facility operators still need to provide dose evaluation and join the treating plan discussion (especially for physical dose in a n+γ mixed field and for RBE study). In order to run this BNCT facility smoothly, the following resources should be acquired in the next 5 years.

a. One researcher in chemical background to assist the development of boron containing drugs used for BNCT and another one in medical physics background to communicate/collaborate with the hospital to run the BNCT program.

b. Two technicians to fulfill the minimum requirement for THOR operation. (Table 2 shows the total operators for 2MW research reactor in the world)

c. At least 2 millions per year to maintain the THOR and BNCT facility.

For the ageing management program, no additional and specific resources are required as they can be obtained through funded projects by TPC.

5. Strategic planning and countermeasures at the university level

THOR is operating with declining budgets, and external revenues are often required to reimberse part of the reactor operating costs. In order to balance the budgets, we have to minimize the operating costs while maximizing the external services, such as RI production, NAA services, and international neutron beam-line project. Since THOR is the only nuclear research reactor still in operation in Taiwan, it is essential to keep this reactor running in the next 10 years for the purpose of BNCT, radioisotopes production, and for supporting the international neutron beam-line project.

Table 1. The comparison of epithermal neutron beam parameters between THOR current design and measurements of current BNCT facilities (Binns, et al., 2002)

Reactor	MIT FCB	R2-0	FiR	Rez	HFR	WSU[a]	THOR[b]
Country	USA	Sweden	Finland	Czech	Netherlands	USA	ROC
Power (MW)	5	0.5	0.25	9	45	1	1~2
Aperture (cm)	12	14x10	14	12	12	10	14
Φ_{epi} (10^9 n/cm^2/s)	4.2	1.43 (1.8)[c]	1.1 (1.1)[c]	0.68	0.33	4.1	1.69[d]
$\dot{D}_f / \Phi_{epi}$ (10^{-11} cGy*cm^2/n)	1.4	8.3 (0.8)[c]	3.3 (2.4)[c]	16.9	12.1	3.0	2.8[d]
$\dot{D}_\gamma / \Phi_{epi}$ (10^{-11} cGy*cm^2/n)	3.6	12.6 (5.2)[c]	0.9 (0.5)[c]	10.8	3.8	--	1.25[d]

[a] Nigg, et al., 2002

[b] All values are measurements except for THOR.

[c] The values in ( ) are calculated values (Skold, et al., 2000).

[d] Calculated values of present beam design for THOR at 1MW

Table 2. Total operators for 2MW research reactor in the world

Country	Reactor	Operators	MWD/yr	Crit. Date
Thailand	TRR-1/M1	19	88	1977/11/7
Indonesia	BANDUNG	16	0	1964/10/19
United States	FNR	13	500	1957/9/18
Netherlands	HOR	12	320	1963/4/25
Norway	JEEP II	12	510	1966/12/1
Taiwan, ROC	THOR	8(4)*	55	1961/4/13
United States	UC DAVIS	8	300	1990/1/20
Egypt	ETRR-1	7	96	1961/2/8

* 4 operators will retire within next 5 years