Present Status and Future Perspectives of Research and Test Reactor in Japan

Yoshihiko KANEKO* and Keisuke KAIEDA**

*Atomic Energy Research Laboratory, Musashi Institute of Technology
**Department of Research Reactor, Japan Atomic Energy Research Institute

ABSTRACT

Since 1957, Japan Atomic Energy Research Institute (JAERI) has constructed several research and test reactors to fulfill a major role in the study of nuclear energy and fundamental research. At present four reactors, the Japan Research Reactor No. 3 and No. 4 (JRR-3M and JRR-4 respectively), the Japan Materials Testing Reactor (JMTR) and the Nuclear Safety Research Reactor (NSRR) are in operation, and a new High Temperature Engineering Test Reactor (HTTR) has recently reached first criticality and now in the power up test. In 1966, the Kyoto University built the Kyoto University Reactor (KUR) and started its operation for joint use program of the Japanese universities.

This paper introduces these reactors and describes their present operational status and also efforts for aging management. The recent tendency of utilization and future perspectives is also reported.

1. INTRODUCTION

In 1957, JAERI was established as a central research organization with a purpose of contributing to atomic energy research, development and utilization, in implementation of the Japanese national program. Four research reactors, JRR-1, JRR-2, JRR-3M, and JRR-4, one materials testing reactor JMTR, and one pulse reactor NSRR were successively constructed.

JAERI recently built a new test reactor HTTR, which reached an initial critical in 1998 and is now in power up test. In 1964, the Kyoto University built KUR and started its operation for joint use program of the Japanese universities.

The numbers of research and test reactors and critical assemblies, which are now operated or were operated until some years ago are listed in **Table 1**.

Table 1 Research and test reactors and critical assemblies in Japan

	Thermal	Fast
Research Reactor	9 (3)	1 (1)
Test Reactor	2	1
Critical Assemblies	8 (1)	1

( ) University Reactor

The number of the research reactors and that of the test reactors each with the thermal neutron spectra are 9 and 2 respectively. In addition, the number of the critical assemblies with thermal neutron spectra is 8. It is to be noted that the total 5 reactors belong to the universities. Histories of each reactors and critical assemblies are shown in **Figure 1**. X-axis shows the date of start and stop of operation. The names of the facilities are indicated along with Y-axis. For example, JRR-2 reached initial critical in 1960 and stopped its operation in 1996 for preparation of decommissioning. The area painted in orange shows the period in which operation had been done.

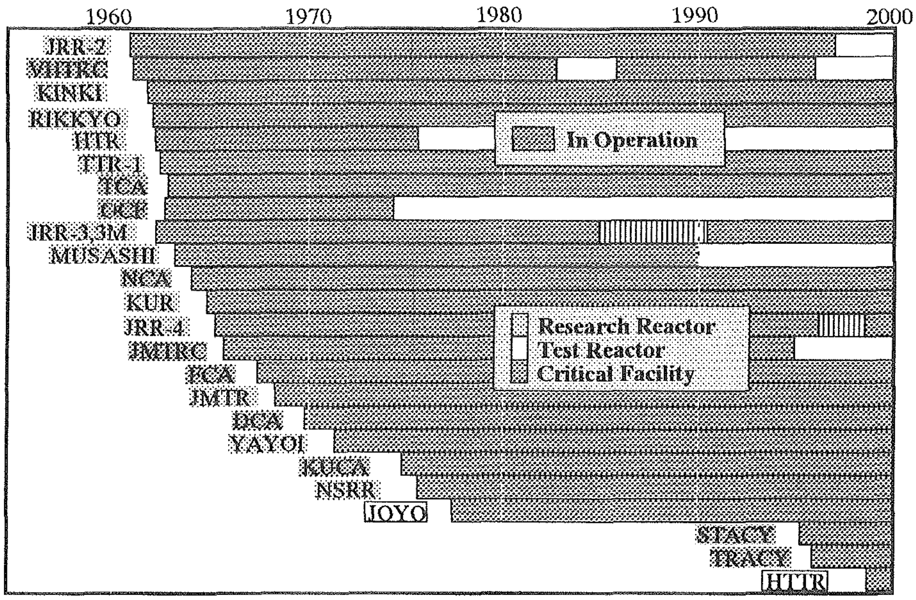


Figure 1 History of research/test reactors and critical assemblies in Japan.

Most facilities were built before 1975 each with somewhat wide purpose. Their original purposes have been mostly attained to the present and new targets are being identified.

Aiming at achieving them the facilities were modified so as to get upgraded neutron fields. Efforts against aging problems were undertaken in the chance of the modifications. Some reactors, which could not find new targets, were already shut down.

In most reactors, enrichments of the core fuels have been reduced in the past 20 years, in accordance with the Reduced Enrichment Research and Test Reactor Program.

The JRR-3M reactor restarted its operation in 1990 after large-scale modification. JRR-4 started its operation just after KUR and had been modified around 1998 and restarted. JMTR started its operation in the late 1960's, and still in operation. Renewal of some components has been performed for the aging problem.

The brief explanations on the present status of the 5 representative reactors are going to be given in the succeeding chapters, according to the order of origination. They are JRR-3M, KUR, JRR- 4, JMTR and HTTR.

2. JRR-3M

JRR-3M is a tank type light water moderated and cooled research reactor with thermal out put of 20MW. The core was converted from 20% EU UAl_x-Al to 20% EU U_3Si_2-Al fuels in this year 1999. Burn up exceeding 60% can be expected, which is able to reduce significantly the amounts of spent fuels.

Most experimental facilities such as neutron scattering facilities, cold neutron source and neutron guide tubes are upgraded. Fundamental researches including material and life sciences are enhanced there. Radio activation analyses are also facilitated, using prompt gamma ray analyzer. Silicon doping facility was modified so as to treat very large diameter cylinder samples.

Revised neutron radiography facility enhanced basic research in wide area including thermo-hydrodynamics.

In order to overcome the aging change problems, an almost new core was built in the occasion of dismantling of the original JRR-3 around 1990. Major components including the instrumentation and control system were replaced. Some recent results of experiments carried out in JRR-3M will be given here.

Figure 2 shows the tertiary structure of the lysozyme protein determined by the neutron diffraction method. The positions of H_2O molecule are clearly determined. **Figure 3** shows the distribution of water in a carnation cut flower determined by the neutron radiography method.

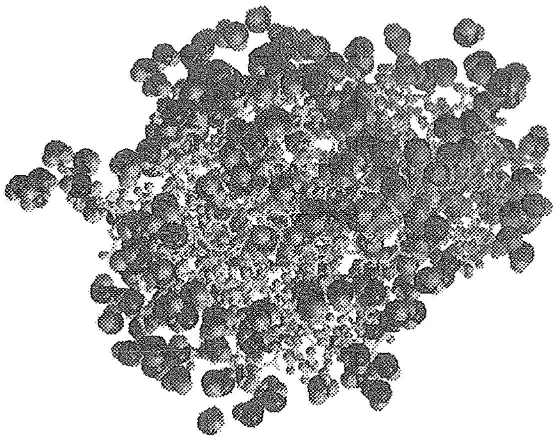
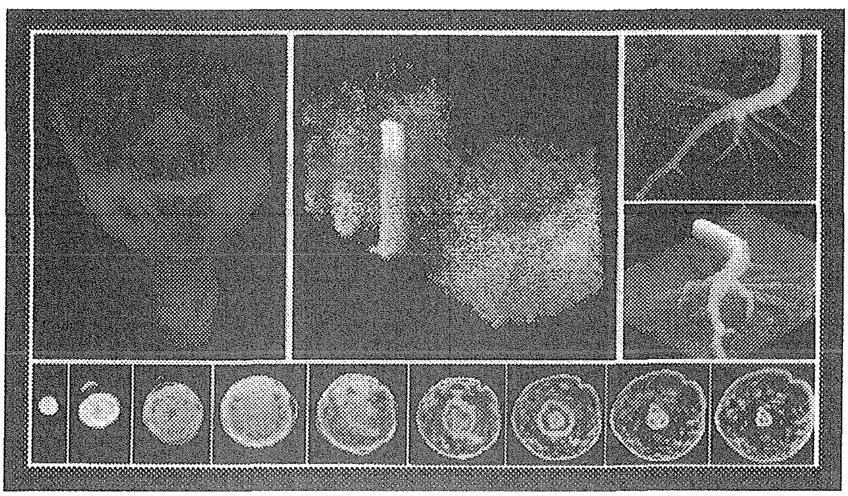


Figure 2 Structure of lysozyme protein determined by neutron diffraction.



by courtesy of Prof. T.M.NAKANISHI

Figure 3 Water image in a carnation flower and a soybean root by neutron beam analysis

3. KUR

KUR is a pool type light water moderated and cooled research reactor with thermal out put of 5MW. Its core is mainly loaded with 93% EU U-Al and partially with 20% EU U_3Si_2-Al for test.

Recently, experimental facilities have also been well upgraded. Production of epithermal neutrons is made possible in the D_2O facility, aiming at improved medical usage. A shielding shutter system was provided so as to perform the medical irradiation along with any time schedule, intersecting a cycle of long continuous operation. Precise temperature control was made possible for material and fuel irradiation to satisfy the experimental demands. Current research activities include geochemistry, environmental science, life and medical sciences, and neutron capture therapy.

Counter measures against aging change problems were undertaken;

- Renewal of the main heat exchanger
- Replacement of the inner tank of the D_2O facility
- Renewal of the reactor control console and emergency power source

Figure 4 shows the overview of the KUR reactor room. In the center, we can see the reactor core surrounded by the concrete shields. In the left side the cold neutron source is located. In the right side, the medical irradiation zone is seen.

Figure 5 indicates the molecular structure of Borocaptate used in BNCT. This chemical substance gathers selectively in the tumor. This substance, therefore, plays an important role in destroying cancerous cells.

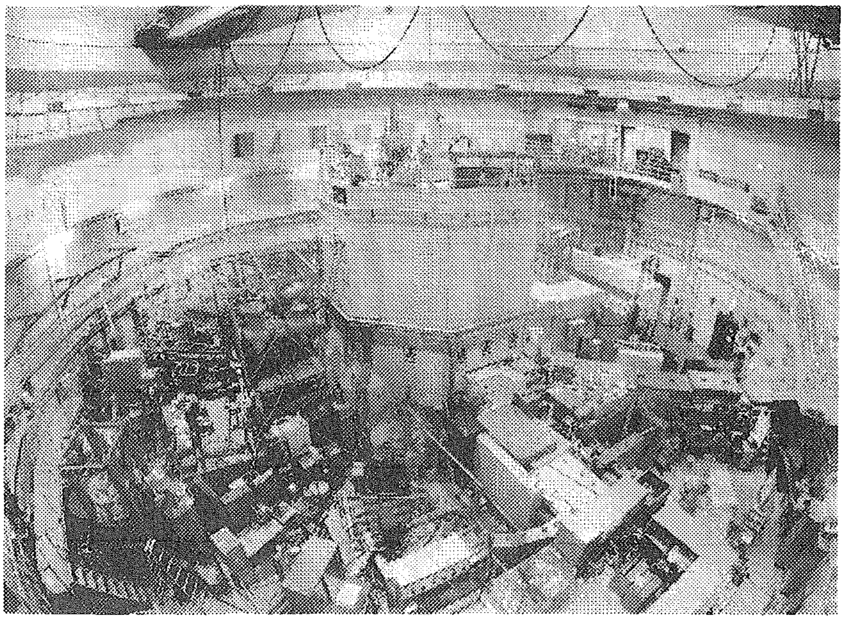


Figure 4 Overview of KUR reactor room.

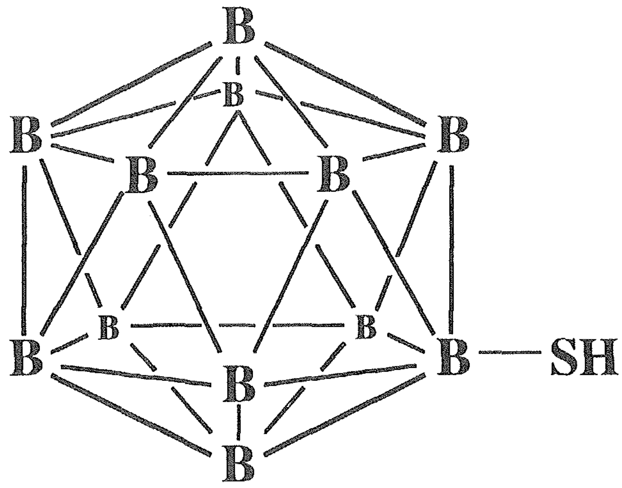


Figure 5 Molecular structure of borocaptate used in BNCT.

4. JRR-4

JRR-4 is a research reactor with thermal out put of 3.5 MW. Its core was converted from 93% EU-Al to 20% EU U_3Si_2-Al in 1996. This reactor is of pool type and light water moderated and cooled. In case of the core conversion, this reactor was totally modified, so as to accord with the new national guide lines for safe design and evaluation of safety.

Upgrade of the experimental facilities related to BNCT for Brain Tumor was done. In addition, prompt gamma ray analyzer and silicon irradiation systems are installed.

Some efforts are made for aging change problem;

- Improvements in resistant properties for earthquake,
- Update of instrumentation and control systems,
- Installation of emergency exhaust system

Figure 6 shows the new medical irradiation facility, and an example of estimated radiation dose estimated on time by calculation.

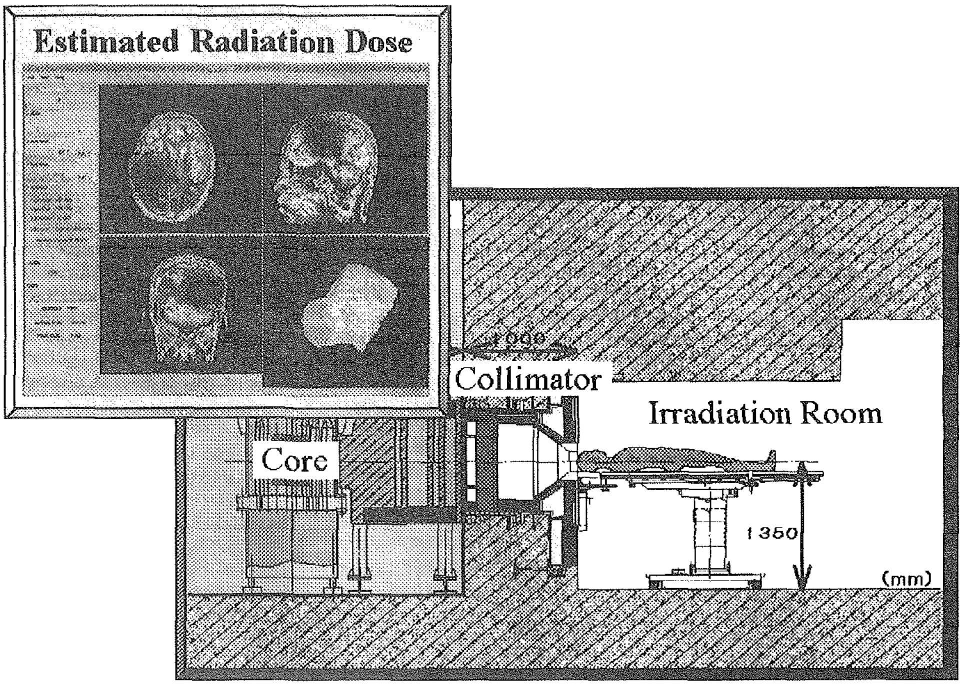


Figure 6 Medical irradiation facilities in JRR-4

5. JMTR

JMTR is a test reactor with thermal out put of 50MW. Its core was converted from 45% EU U-Al to 20% EU U_3Si_2-Al in 1996. This reactor is of MTR type, cooled and moderated with light water. In case of the core conversion, performance improvements were made with use of cadmium wire burnable poisons built in fuel assemblies.

Operation duration time was lengthened from 12 to 25 days. Change of the spatial distributions of the neutron flux throughout the core was made small.

Some improvements in irradiation facilities were done so that integrity of high burn-up BWR fuels against power level change were well investigated. Irradiation tests of the materials for the fusion reactor started as a new task. Because in some case only very small samples are available for fusion reactor materials like vanadium metal, a post irradiation test technique using very small samples was developed.

It is to be noted that several counter measures were taken for the aging problem;

- Renewal of the secondary cooling systems piping
- Update of the control cables
- Renewal of the cooling tower
- Renewal of the emergency power source

Figure 7 indicates the pebbles of Li_2O which are to be used for a fusion reactor blanket. Irradiation tests are being done for their functional characteristics of producing and releasing of tritium gas.

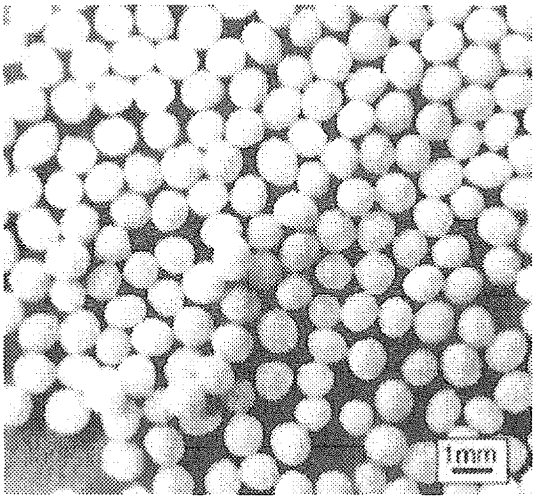


Figure 7 Irradiation test of functional materials of fusion blanket

6. HTTR

HTTR is a test reactor with thermal out put of 30MW. This reactor is of type of High Temperature Gas Cooled Reactor. Its core is loaded with pin in block type coated particle fuels. The core is cooled with helium gas with out-let temperature of 850°C~950°C and with pressure of 60MPa. HTTR was built with aiming at facilitating the technology in use of nuclear heat.

Figure 8 shows the future perspectives of usage of nuclear heat, all of which are evaluated to be well competitive with the existing ones based on the fossil fuels;

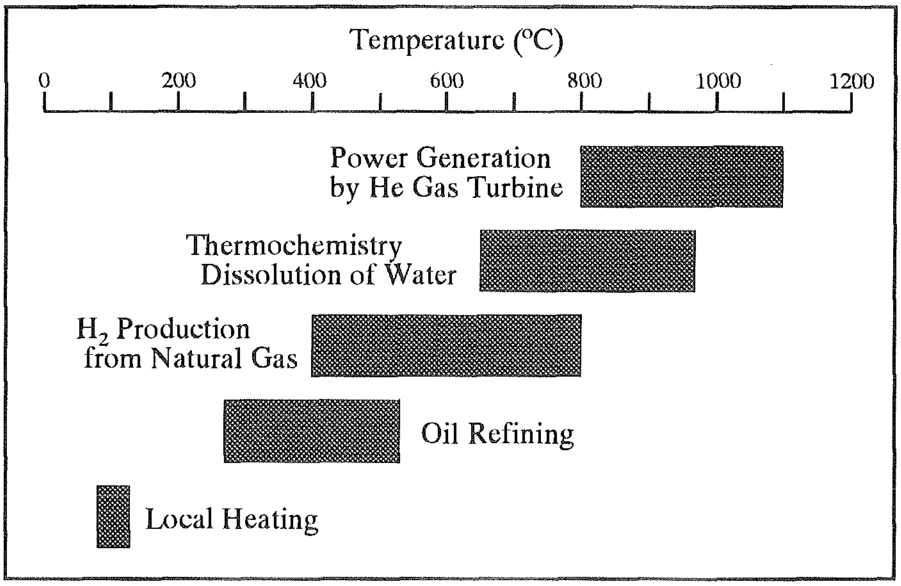


Figure 8 Utilization of Nuclear heat.

- Power generation by helium gas turbine
- Thermo-chemical dissolution of water
- H_2 production from natural gas

- Oil refining
- Local heating

In the figure, indicated are the required helium gas temperatures

7. CONCLUSION

Research and test reactors in Japan have been contributing to extend the basic researches and nuclear engineering.

Universities joint use program will facilitate the basic researches.

The High Temperature engineering Test Reactor, HTTR will open the window to new application area of nuclear energy in the coming 21st century.

Human resource development is a very important issue. Training using the small research reactors will be still effective to develop good human resources as it was in the 20th century.