PRESENT STATUS AND FUTURE POTENTIAL FOR COMMERCIAL APPLICATION OF JAEA RESEARCH REACTORS

A.M. ISHIHARA, H. KAWAMURA
Japan Atomic Energy Agency, Oarai Research & Development Center,
Oarai-machi, Ibaraki-ken,
Japan
masahiro.ishihara@jaea.go.jp

1. INTRODUCTION

In the check and review discussion of the Japan Materials Testing Reactor (JMTR) reactivation, the Japan Atomic Energy Agency (JAEA) has surveyed utilization fields for Materials Test Reactors among other research reactors. From the survey, it has been concluded that the utilization of research reactors can be categorized into four major application targets:

(i) Lifetime extension of LWRs, e.g., aging management of LWRs, development of next generation LWRs;
(ii) Progress of science and technologies, e.g., next generation reactors such as the high temperature gas cooled reactor (HTGR), fusion reactor, basic research on nuclear energy, neutron beam utilization;
(iii) Expansion of industrial use, e.g., doping of silicon semiconductor, radioisotope (RI) production, production of ^{99m}Tc for the medical diagnosis medicine;
(iv) Education and training of nuclear scientists and engineers.

These are thought to be common in the world.

JAEA has developed a fleet of four different types of research reactors, Japan Research Reactor-3 (JRR-3), JRR-4, Nuclear Safety Research Reactor (NSRR) and JMTR designed specifically for intended purposes. JRR-3, with a thermal power of 20 MW, is applied to beam experiments, irradiation tests, RI production, activation analysis and silicon semiconductor doping. JRR-4, with a thermal power of 3.5 MW, is designed for medical irradiation such as boron neutron capture therapy (BNCT), RI production, and education and training. NSRR, with a maximum power of 23 GW at pulse operation, is utilized for nuclear fuel safety research. Finally, JMTR, with a thermal power of 50 MW, is devoted to irradiation tests for nuclear fuels and materials, and RI production. The role of research reactors in JAEA is summarized in Table 1.

JMTR and its reactor facilities are now under refurbishment. The refurbished JMTR is expected to gain an appreciable income from commercial users. A few successful examples on JMTR utilization are shown in this paper from a viewpoint of commercial applications. Since the strengthened regional and international cooperation is a key issue to enhance the steady commercial applications such as RI production, the importance of regional and international frameworks is also mentioned.

TABLE 1. ROLE RESEARCH REACTORS IN JAEA

Items \ Reactor	JMTR (50MW)	JRR-3 (20MW)	JRR-4 (3.5MW)	NSRR (23GW*)
Lifetime extension of LWRs	○			○
Progress of science and technology	○	○		
Expansion of industry use	○	○	○	
Education and training	○		○	

* : Pulse operation

2. RESEARCH REACTORS IN JAEA

2.1. Outline of research reactors

JAEA has developed four different research reactors: JRR-3, JRR-4, NSRR and JMTR.

JRR-3 is a light water moderated and cooled pool type reactor with 20 MW of thermal power. Its first criticality was achieved in 1962, and remodeling was carried out in 1985. In 1990 the remodeled JRR-3 was re-started for utilization. The thermal flux is at maximum 3×10^{18} $m^{-2}s^{-1}$, and the operation mode is 26 days per cycle with 6 to 7 cycles per year. Specifications and a view of the reactor are shown in FIG. 1.

JRR-4 is a light water moderated and cooled swimming pool type reactor with 3.5 MW of thermal power. The first criticality was achieved in 1965, and radiation shielding experiments for the nuclear ship *Mutsu* were started in 1966, followed by training for reactor engineers beginning in 1969. The thermal flux is 7×10^{17} $m^{-2}s^{-1}$ at maximum, and daily operation with 6 hours per day is carried out. Specifications and a reactor view are shown in Figure 2.

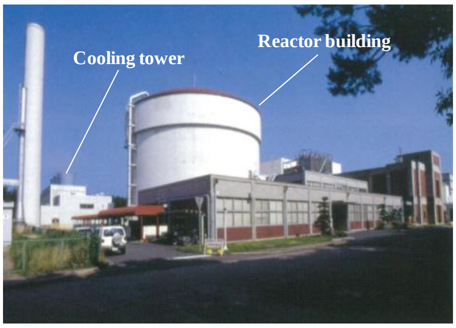
NSRR is a pulse reactor with the maximum power of 23 GW at pulse operation and 300 kW at steady state operation. The first criticality was achieved in 1975, and modification of experimental facilities and the reactor control system was carried out in 1989. Spent fuel experiments started in 1989, and spent mixed oxide (MOX) fuel experiments started in 1996. In 2006, high burnup fuel and MOX fuel experiments as well as high pressure water capsule experiments were started. Specifications and a reactor view are shown in Figure 3.

JMTR is a light water cooled tank type reactor with 50 MW of thermal power. The first criticality was achieved in 1968, and user operation was carried out from 1970 to 2006. Now refurbishment works are being carried out until 2010. The thermal and fast fluxes are almost the same at 4×10^{18} $m^{-2}s^{-1}$ at maximum, and the operation mode is 30 days per cycle with maximum 6 cycles per year. Specifications and areactor view are shown in Figure 4.

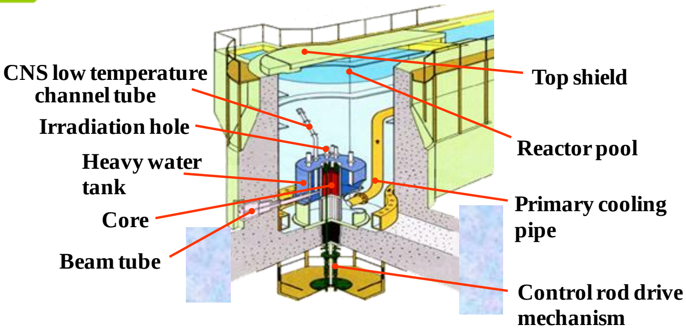
1962 First criticality
1985 Remodeling works start to achieve high performance
1986 Take out reactor core
1990 Criticality & Utilization start
1993 Cumulative output reached at 10,000MWD
1998 High density fuel loading (LEU/Si/Al dispersion fuel)
2006 Cumulative output reached at 50,000MWD

Specifications of JRR-3

Purpose	Beam experiment, Fuel/material irradiation, RI production, Activation analysis, etc.
Type	Light water moderated and cooled pool type
Fuel	LEU/Si/Al dispersion fuel
Thermal power	20 MW (max.)
Thermal flux	3×10^{18} n/m^2・s (max.)
Core	Cylinder shape (60cm dia. 75cm in height)
Operation mode	26 days/cy, 6-7 cy/year



View of Reactor building



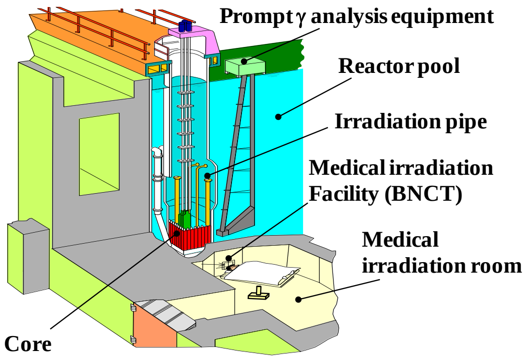
Reactor core

Fig. 1. Specifications and reactor view of JRR-3.

1965First criticality
1966 Thermal power at 2500 kW, Radiation shielding experiment start for nuclear ship "MUTU"
1969 Training start for reactor engineers
1974 Outside utilization start
1999 Thermal power at 3500kW
1996 LEU fuel, Update reactor facilities & utilization facilities
1998 Outside utilization restart

Specification of JRR-4

Purpose	Activation analysis, education & training, RI production, Medical irradiation, radiation shielding experiment
Type	Light water moderated and cooled swimming pool type
Fuel	LEU/Si/Al dispersion fuel
Thermal power	3,500 kW s (max.)
Thermal flux	7×10^{17} n/m^2・s (max.)
Core	Rectangular (34.4cm×40.5cm, 60cm in height)
Operation mode	Daily operation (6h/day)



Bird's eye view of reactor

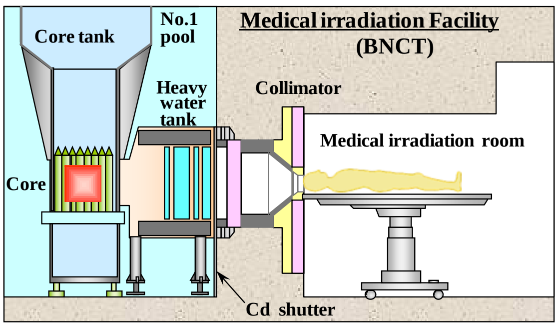
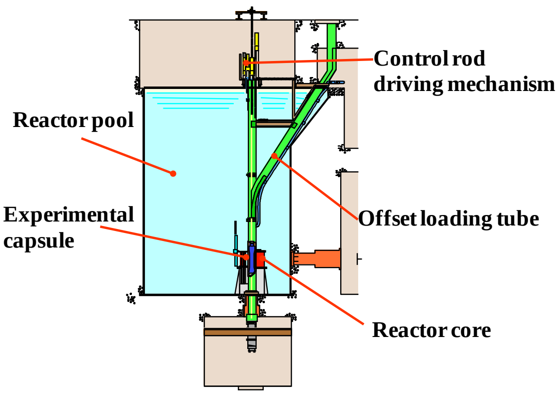


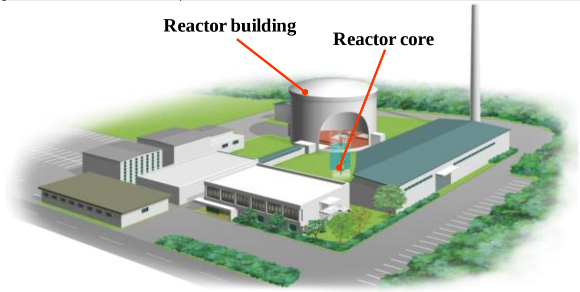
Fig. 2. Specifications and reactor view of JRR-4.

1975 First criticality/ Fresh fuel experiments starts
1980 Succeed in visible capsule experiments
1989 Modification of experimental facilities and reactor control system
Spent fuel experiments starts
1996 Spent MOX fuel experiments starts
2004 3,000 pulse operations achieved
2006 High burnup fuel and MOX fuel experiments starts
High pressure water capsule experiments starts

Specification of NSRR	
Type	Type of Uranium-Zirconium-hydride moderating heterogeneous
Fuel	Uranium-Zirconium-hydride
Maximum Reactor power	300kW (Steady state operation) 23,000MW (Pulse operation)
Maximum neutron flux	1.9×10^{16} n/m²·s (Steady state operation)
Core	Annular core
Operation mode	Steady state operation Natural pulse operation Shaped pulse operation Combined pulse operation



Schematic illustration of NSRR



Cutaway view of NSRR reactor building

Fig. 3. Specifications and reactor view of NSRR.

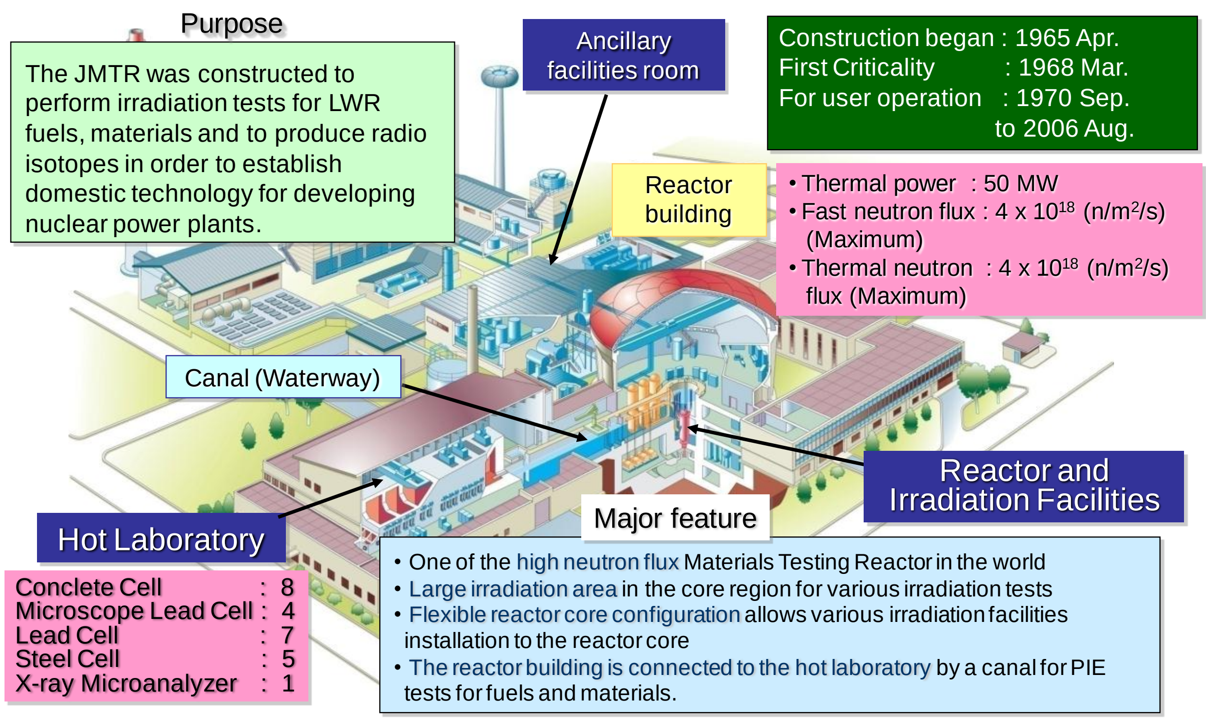


Fig. 4. Specifications and reactor view of JMTR.

2.2. Utilization of research reactors

JRR-3 is applied to beam experiments, irradiation tests, RI production, activation analysis and silicon doping. For beam utilization, JAEA users constitute around 39% of users, and ~~others~~ external users are around 61%. Within external users, around 82% are university users, and around 15% are private users (industry users). For irradiation utilization, the major user is universities; university users are around 50%, private users are around 34%, and JAEA users are around 14%. Utilization of JRR-3 is summarized in FIG.5.

JRR-4 is designed for medical irradiation such as BNCT, RI production and education and training. For BNCT, utilization was carried out 25 times in 2007. For irradiation utilization, the major user is also universities; university users are around 50%, private users are around 36%, and JAEA users are around 10%. Comparatively, for experimental utilization such as radiation shielding experiments, the major users are JAEA personnel; JAEA users are around 74%, university users are around 17%, private users are around 9%. Utilization of JRR-4 is summarized in Figure 6.

JMTR is devoted to irradiation tests for nuclear fuels and materials, and RI production. The major irradiation field is the progress of science and technologies (e.g., fundamental research, fusion reactors and high temperature gas cooled reactors) which covers 58%, followed by the light water reactor (LWR) related field with about 21% and RI production with about 15%. From the viewpoint of users, JAEA users comprise about 50%, university users about 30%, RI production users about 15%. Utilization of JMTR is summarized in Figure 7.

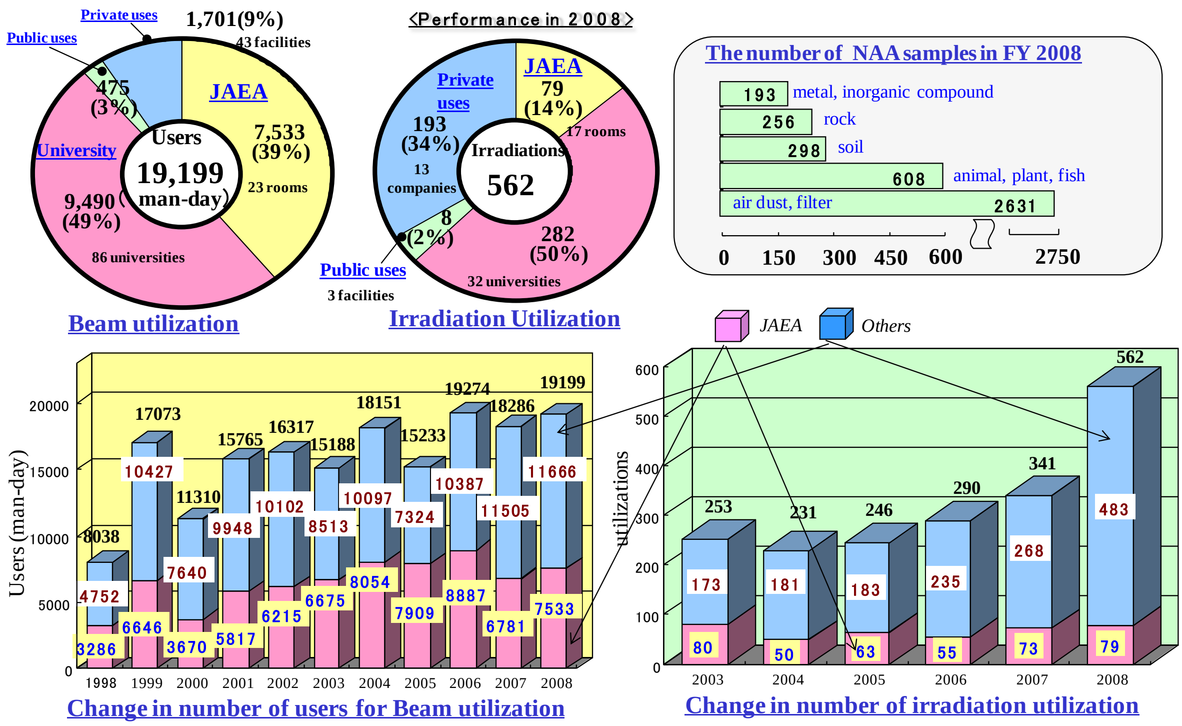


Fig. 5. Utilization of JRR-3.

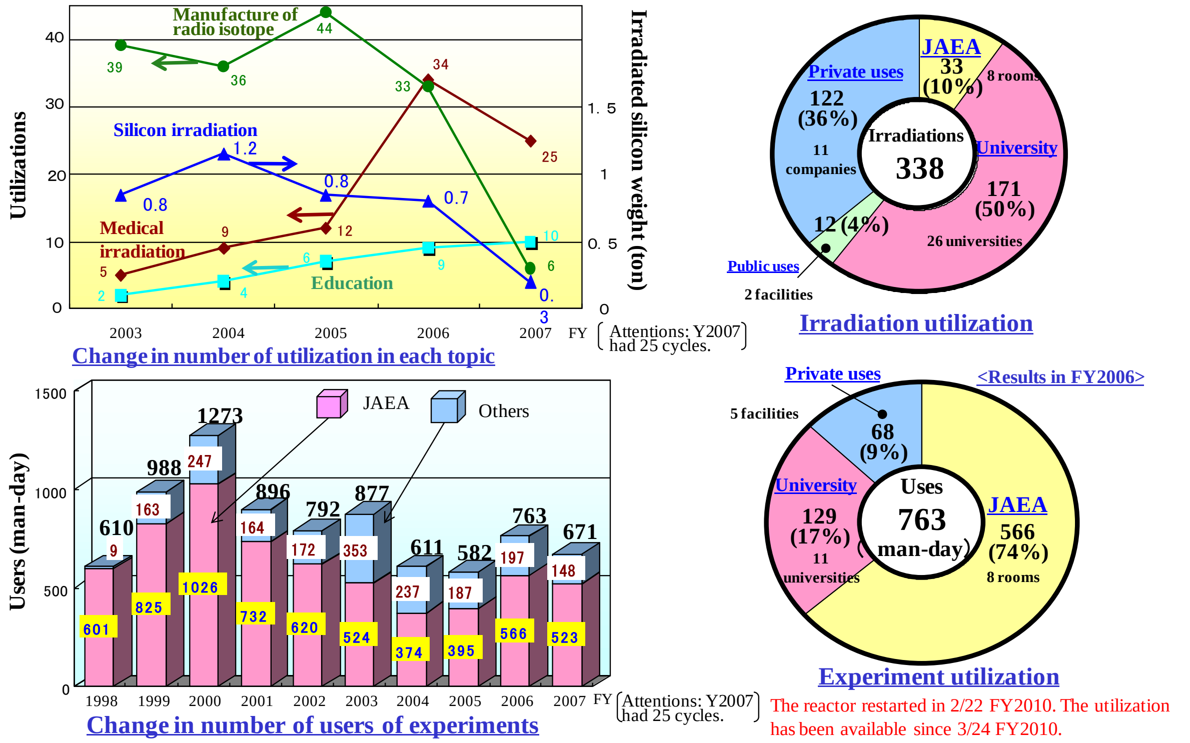


Fig. 6. Utilization of JRR-4.

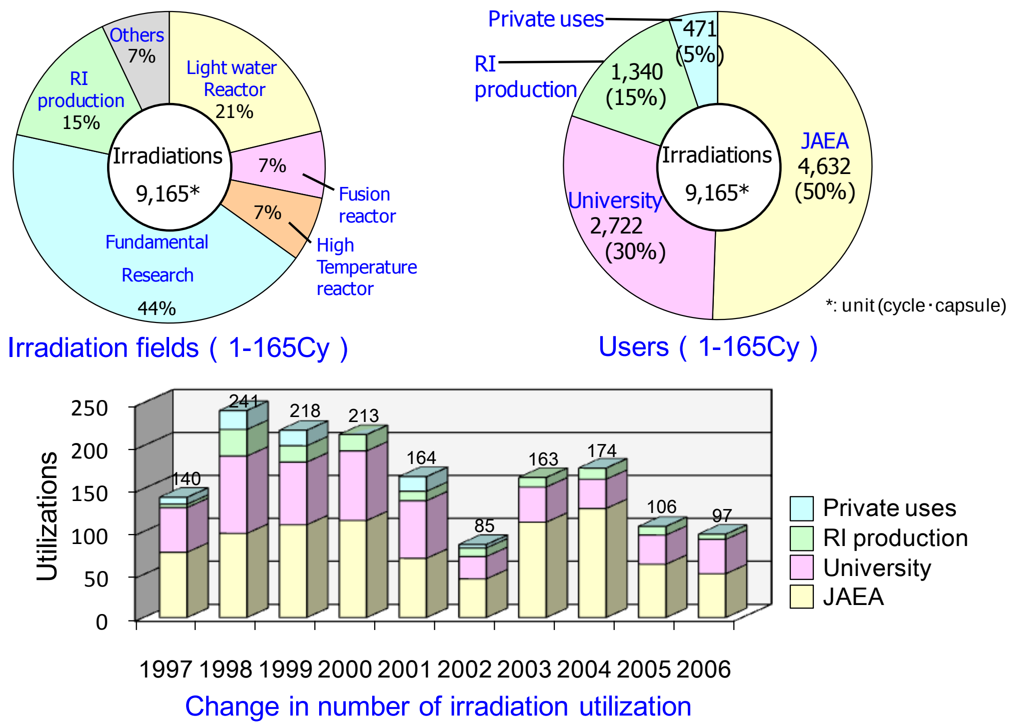


Fig. 7. Utilization of JMTR.

3. COMMERCIAL APPLICATION OF JMTR

3.1. Refurbishment of JMTR

The check and review on restarting JMTR operation was first carried out in November 2005, and after about one year of discussion, the JMTR reactivation was set for December 2006 upon strong user requests. Then, refurbishment works have been ongoing since 2007, and reoperation will be achieved in the 2011 fiscal year. For the reactivation of JMTR, JAEA announced that external utilization will be promoted corresponding to users' opinion, and that the usability of the JMTR will be improved to provide attractive circumstances to users.

From a user's standpoint, the following measures will be taken:

- Achievement of a reactor availability factor of 50% to 70%;
- Establishment of a simple irradiation procedure and satisfied technical support system;
- Shortening of turnaround time (time from application to obtain data) to get irradiation results earlier;
- Realization of attractive irradiation costs in comparison with other testing reactors in the world;
- Security of business confidence by information control and other measures.

For the first item, the achievement of a higher reactor availability factor, the possibility of reactor scram by an accident will be decreased by the replacement of reactor components. In addition, even if the failure of components occurs, repairing the failed components will also become easier due to the replacements. Consequently, these measures will shorten the time of unavailability. Actually, the JMTR has already achieved a high number of operation days per year, twice boasting more than 180 days in a year. Then, the replacement of old and unreliable components leads to a higher reactor availability factor. Furthermore, optimization of the overhaul time of the reactor, defined once per year by the Nuclear Safety Commission of Japan, will also create a longer operation period during a given year. The operation of the new JMTR will achieve at least 210 days per year as shown in Figure 8.

For the second item of the technical support system, specialists of irradiation technology and irradiation research, such as specialists of reactor fuel and reactor materials, are necessary to discuss sufficiently with users on the details of irradiation methods and conditions at the planning stage.

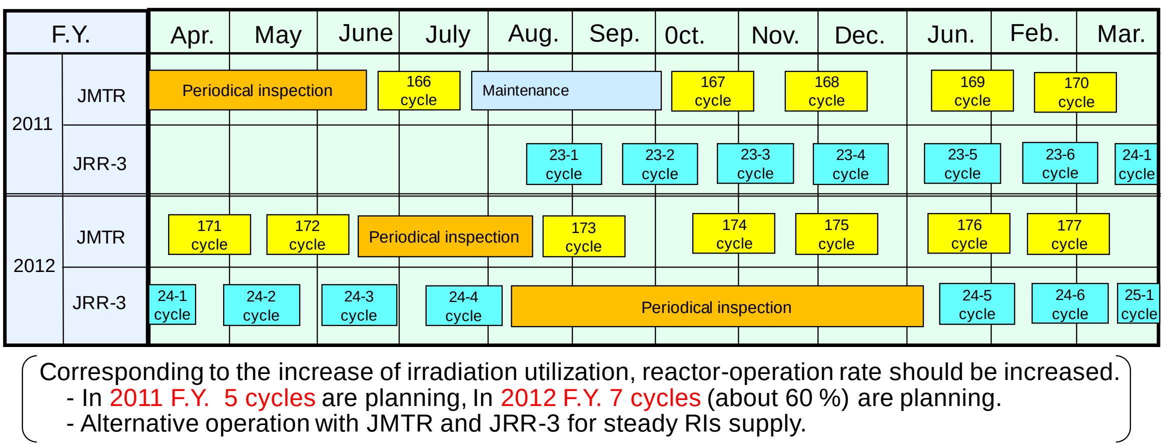


Fig. 8. Operation plan of new JMTR.

This is an example of the improvement of the reactor's usability that will improve the experience of many users due to the fulfillment of the technical support system.

3.2. Promotion of utilization

To increase the reactor's utilization, it should be necessary to contact several user groups with potential for JMTR usage, as shown in Figure 9. Some kinds of irradiation programmes need advanced irradiation facilities that are not installed in JMTR. In this case, a user's fund is necessary to install the new facilities. As an example of this case, new facilities of safety research for light water reactor (LWR) materials and fuels are under preparation stage based on the user's fund. The key point to promote utilization is to provide highly valuable data to users with advanced irradiation technologies.

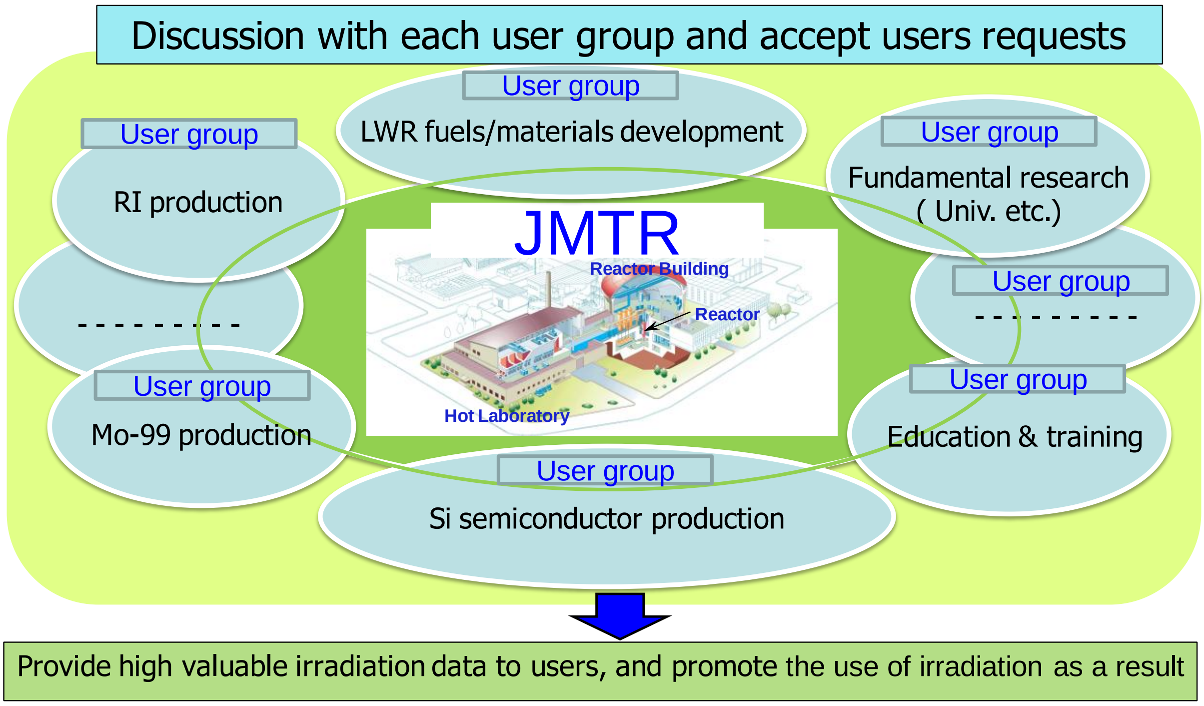


Fig. 9. Increase of irradiation utilization.

3.3 Proposal of international network

The new JMTR will contribute research and development utilization as well as industrial utilization by offering excellent irradiation technologies. In irradiation, an attractive irradiation test will be proposed by developments of advanced technologies such as new irradiation technology, new measurement technology and new Post Irradiation Examination (PIE) technology. Furthermore, cooperation with various nearby PIE facilities surrounding the JMTR will be established to extend the capability of PIEs after ongoing discussion with the nearby facilities.

Construction of a world network is one proposal to achieve efficient facility utilization and providing high quality irradiation data by role sharing of irradiation tests with Materials Test Reactors in the world, as shown in FIG.10. As the first step, mutual understanding among Materials Test Reactors is thought to be necessary. Following this point, an international symposium on Materials Test Reactors, ISMTR, was held at JAEA in 2008 for the purpose of world network construction. The 2nd ISMTR was held in the US in 2009 and the 3rd was held in the Czech Republic. The 4th ISMTR will be held in Argentina during next year.

In the Asian area, some excellent testing reactors are operated currently such as HANARO in Korea and OPAL in Australia. Each of these reactors has individual and original characteristics and takes a supplementary role with respect to each other. The JMTR has a plan to contribute greatly to users by construction of an internationally utilized facility as an Asian center of testing reactors.

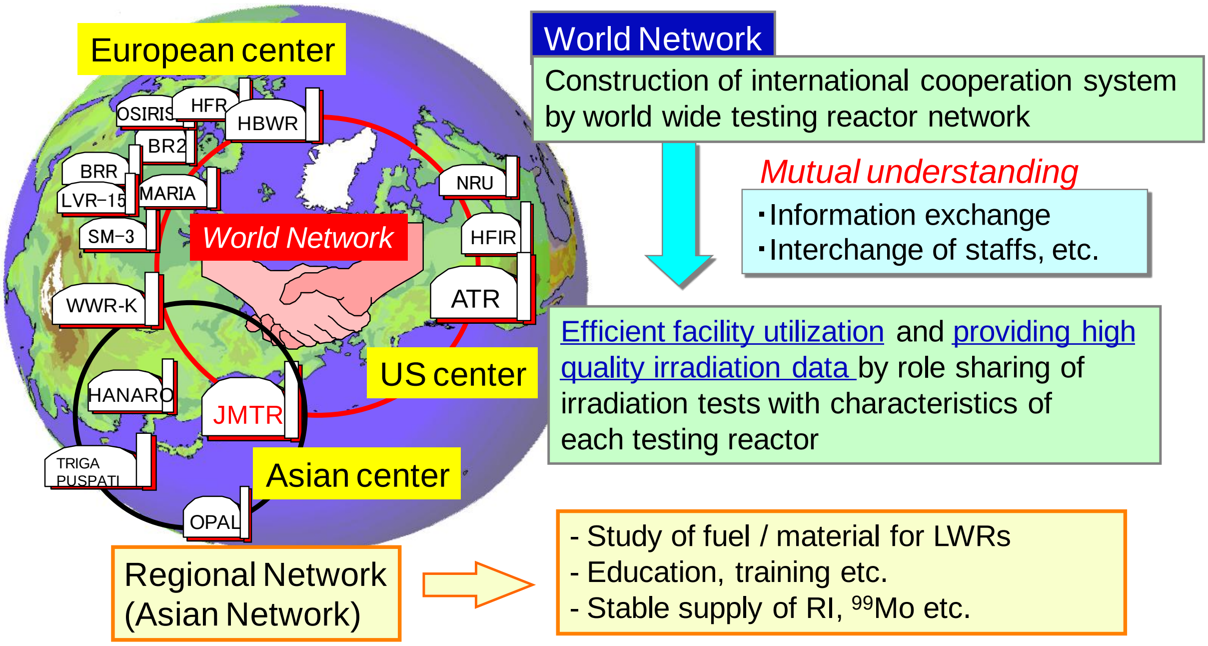


Fig. 10. Increase of irradiation utilization.

4. CONCLUSIONS

From user surveys of Materials Test Reactors among other research reactors, utilization of research reactors can be categorized into four major application targets: LWR related R&D, progress in science and technologies, industrial use, and education and training of nuclear scientists and engineers.

JAEA has developed four different research reactors: JRR-3, JRR-4, NSRR and JMTR, designed specifically for intended purpose. The utilization status for these reactors was introduced in this paper.

JMTR and its reactor facilities are now under refurbishment. The refurbished JMTR is expected to gain an appreciable income from commercial users. A few successful examples of JMTR utilization were presented in this paper from a viewpoint of commercial application. Since strengthened regional and international cooperation is a key issue to enhance the steady commercial applications such as RI production, the importance of regional and international framework was also mentioned.