Refurbishment Status and Future Program of Japan Materials Testing Reactor (JMTR)

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Abstract

The Japan Materials Testing Reactor (JMTR) of Japan Atomic Energy Agency is a light water cooled tank typed reactor with first criticality in March 1968. Owing to the connection between the JMTR and the hot laboratory by a canal, post irradiation examinations and re-irradiation tests can conduct easily with safe and quick transportation of irradiated samples.

The JMTR has been applied to fuels/materials irradiation tests for LWRs, HTGR, fusion reactor and RI production. However, the JMTR operation was once stopped at August 2006, and the refurbishment works are now conducting. The reactor facilities will be renewed taking four years from the beginning of FY 2007, and necessary examination and works are being carried out on schedule.

The renewed JMTR will be started from FY 2011, and be operated for a period of about 20 years until around FY 2030. The usability improvement of the JMTR, e.g. higher reactor availability-factor, shortening turnaround time to get irradiation results, attractive irradiation cost, business confidence, is also discussing with users as the preparations for re-operation.

In the paper, status of the refurbishment of reactor facilities are introduced, moreover the future program using the JMTR will be prescribed.

Keywords: JMTR, Material Testing, Refurbishment, Irradiation, LWR, RI Production

1. INTRODUCTION

The Japan Materials Testing Reactor (JMTR) in Japan Atomic Energy Agency (JAEA) is a light water cooling tank typed reactor with thermal power at 50MW. The JMTR is connected with the hot laboratory by a water canal as shown in Fig.1. This is an advantage in post irradiation experiments (PIEs) and re-irradiation tests. Namely, since irradiated samples are transferred safely and quickly between them through the canal, PIEs as well as re-irradiation tests can be carried out easily and speedy.

The first criticality was achieved in March 1968, and the JMTR has been utilized for basic and applied researchers on fuels/materials of fission reactors and fusion reactors. Power ramping tests for the nuclear fuels was, for example, performed to study the integrity/safety of fuels. Radioisotopes were also produced using the JMTR, and were widely used in the medical treatment, industries and agriculture [1-3].

By the user's strong request to the JMTR utilization, the operation was stopped from August, 2006, and then the refurbishment works started from the beginning of FY 2007. At first, aging components were investigated, and their integrity was confirmed; it was clear that the condition of primary and secondly cooling pipes and so on was good [4,5]. Taking account of a continuous operation with safety, reactor facilities/equipments to be renewed were decided; control rod drive mechanism, reactor control system, primary cooling pumps, secondary cooling pumps, electric power supply system and so on, were decided to replace. Now, designs of the replacement components were finished, and fabrications are ongoing as scheduled [6]. The renewed and upgraded JMTR is to be operated from FY 2011, and for a period of about 20 years operation (until around FY 2030) is planned.

At the same time, usability improvement is also under discussion to make a good and suitable condition for users. The discussion is focused on the achievement of higher reactor availability-factor [7], shortening turnaround time to get irradiation results, attractive irradiation cost, business confidence.

2. OUTLINE OF JMTR

The JMTR has been utilized in wide fields of research and developments with high thermal/fast neutron flux using many types of irradiation capsules. Its specification is summarized in Table 1.

The reactor pressure vessel, 9.5m high with 3m in inner diameter, is made of low carbon stainless steel (SUS304L) and is located in the reactor pool. The control rod drive mechanisms are placed under the pressure vessel to make an easy handling of the irradiation facilities and fuels as shown in Fig.2. The core of the JMTR is in a cylindrical shape with 1.56m in diameter and 0.75m in height. The core consists of 24 standard fuel elements, five control rods with fuel followers, reflectors and H-shaped beryllium frame.

Cooling water in a primary cooling system is pressurized at about 1.5MPa to avoid local boiling in the core during power operation. The heat generated in the core is removed by the cooling water in the primary cooling system. The cooling water flows downwards in the core to transfer the heat from the core to the secondary cooling system through heat exchangers. Finally, the heat transferred to the secondary cooling system is removed away into the atmosphere by cooling towers as shown in Fig.3.

For the irradiation, the JMTR provides excellent irradiation performance as shown in Fig.3. About 60 capsules are possible to irradiate simultaneously under various irradiation conditions with maximum neutron flux $4x10^{18}$ $n/m^2/s$ (for thermal and fast neutrons) at temperatures from 50 to 2000 degree Celsius. From preliminary investigation on a low-temperature irradiation, it is concluded that the irradiation test below 20 K can be realized [8]. The JMTR provides various irradiation facilities to users, such as many types of irradiation capsules, shroud irradiation facility and hydraulic rabbit irradiation facility. Using these capsules/facilities, various irradiation conditions such as controlled temperature, controlled neutron fluence, controlled surrounding environment, are possible to achieve with specially developed irradiation technologies as shown in Fig.4.

After irradiation tests, irradiated capsules are transferred to the hot laboratory, which is connected to the reactor building through a water canal, to conduct PIEs. Many kinds of PIEs are possible to carry out by the user's requests as shown in Fig.5; e.g. eddy current test, X-ray microscopic analysis, gamma scanning and so on for fuel PIEs, crack propagation test, creep test, fatigue test and so on for material PIEs.

3. PRESENT STATUS OF JMTR

The refurbishment project of the JMTR is promoted with two subjects; the one is the replacement of reactor components, and the other is the construction of new irradiation facilities. Simultaneously, the usability improvement is under discussion to make a user friendly environment as well as a user oriented management.

3.1 Replacement of reactor components

At first, reactor facilities/equipments were reviewed by following items.

- Number of troubles
- Service life time
- Stable preparation of spare parts in future
- Functional degradation by aging, etc.

From considering the results of the review, reactor facilities/equipments to be renewed were discussed by

- Aging during 20 years reoperation,
- Importance grade of reactor facilities/equipments,
- Conditions of facilities / equipments,
- Stable supply of spare parts in the maintenance activities during 20 years.

Taking also account of a continuous operation with safety, reactor facilities/equipments to be renewed were decided. As a result, aged or old-designed components of the control rod drive mechanism, primary cooling system, secondary cooling system, electric power supply system and so on, are to be replaced by present-designed ones. For example, circuits of reactor control system, which consist of a huge amount of relays and soldered wirings, will be replaced by present-designed integrated circuits. Reactor components to be replaced are shown in Fig.6. Renewal of the feed and exhaust air system is carried out at first, and also renewal of utility facilities of electric power supply system, boiler component, etc. is carried out at the same time. Then, facilities in the reactor building are to be finally renewed. The replacement schedule is shown in Fig.7. Now, designs of the replacement components were finished, and fabrications are ongoing as scheduled.

For facilities which are not replaced, e.g. heat exchangers, pressure vessel, secondary cooling towers and so on, their safety was evaluated from a view point of aging. The long-term operation in future will be possible by maintaining the present condition in accordance with the periodic safety review of the JMTR.

After restart of the JMTR, the maintenance activity will be carried out by the maintenance program based on the periodic safety review of the JMTR.

3.2 Construction of new irradiation facilities

Corresponding to the user’s irradiation request, new irradiation facilities, such as irradiation test facilities for materials/fuels, production facilities for silicon semiconductor and medical radioisotopes, will be planned to install in the JMTR. General preparation schedule is shown in Fig.8.

(1) New Material and Fuel Irradiation Tests

New irradiation facilities for materials/fuels tests are being developed and will be installed in the JMTR during four years refurbishment period. The project started from April 2007 by requirements from the regulatory and development uses of LWRs with a purpose of long-term and up-graded operations. Requirements are based on a higher performance utilization of LWRs. For example, irradiation tests for power up rating, longer operation cycles and modified water chemistries for lifetime extension of the power plants are planned to obtain the evaluation data for fuel and materials.

To meet one of these requirements, an irradiation capsule with a larger test section for a large sized specimen of reactor materials is under development in order to investigate the scale effect on the IASCC behavior. Moreover, a new type of a power ramp test facility is also under development to provide the constant surface temperature on test fuel rod during a boiling transient. It is planned to realize the linear power of the test fuel by controlling the pressure of surrounding ^{3}He gas screen, absorber of neutrons.

(2) New Irradiation Facility for Industrial Purpose

One of irradiation facilities for industrial utilization is intended for a production of silicon semiconductor. Here, the irradiation facility will be developed to irradiate a large sized silicon ingot with 8 inches in diameter, which meets the trend requirement in the field of hybrid cars and so on.

Another irradiation facility is intended to provide the ^{99m}Tc for medical use. A hydraulic rabbit irradiation facility, which is well developed and already used for irradiation in the JMTR, can be applied to the production. Now, investigation on production performance and costs are carried out [9], and detail facilities to be installed in the JMTR are under discussion.

3.3 Usability improvement of the JMTR

The usability of the JMTR should be improved to provide attractive circumstances to users. From user’s standpoints, followings are under discussion:

1) Achievement of the reactor availability-factor from 50% to 70%,
2) Establishment of simple irradiation procedure and satisfied technical support system,
3) Shortening of turnaround time to get irradiation results earlier,
4) Realization of attractive irradiation cost in comparison with other testing reactors in the world,
5) Guard of the business confidence by the information control, etc.

For the first item of the achievement of 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, the repairing the failed components will also become easier from the replacement. Namely, these will shorten the time for the out-of-operation. Actually, the JMTR has already achieved a high operation day per year, more than 180days in a year in two times. Then, the replacement of old and unreliable components leads the higher reactor availability-factor. Furthermore, optimization of the overhaul time of the reactor defined once per year by the Japanese regulation will also take a longer operation period during a year.

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 detail irradiation method/condition at the planning stage of the irradiation. This is an example of the improvement of the usability which is easy to use for many users due to the fulfillment of the technical support system.

Other three items from 3) to 5) are being discussed by taking users requests and/or opinion. A user-friendly management must be established by above-mentioned usability improvement.

4. FUTURE PLAN OF JMTR

After finishing the refurbishment works, the JMTR will be operated for a period of about 20 years until around FY2030.

The expected utilization fields of irradiation are :

1) *Lifetime extension of LWRs*, which includes the aging management of LWRs and the development of the next generation of LWRs.
2) *Progress of science and technologies*, which includes the development of fusion reactor materials, development of HTGR (High Temperature Gas cooled Reactor) fuels and materials, the basic research on nuclear energy, etc.
3) *Expansion of industrial use*, which includes the production of silicon semiconductor for the hybrid car and the production of ^{99m}Tc for the medical diagnosis medicine.
4) *Education and training* of nuclear scientists and engineers.

The new JMTR is planned to contribute the research/development utilization as well as the industrial utilization by offering excellent irradiation fields.

In irradiation, an attractive irradiation test will be proposed by developments of advanced technologies such as new irradiation technology, new measurement technology and new PIE technology. Furthermore, the 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.

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

5. CONCLUSIONS

The JAEA placed that the JMTR is a testing reactor which supports the basic technology of the nuclear energy, and decided the refurbishment of reactor facilities during four years from FY 2007. The refurbishment works are ongoing as scheduled from FY 2007. By the replacement of reactor facilities, the failure possibility of each component will decrease, and this leads the improvement of the higher reactor availability-factor in future.

At the same time, irradiation facilities corresponding to user’s needs, such as Nuclear and Industrial Safety Agency, will be installed to contribute the lifetime extension of LWRs by the user’s fund. Additionally, the contribution to the development of the ITER and the industrial use etc., are being discussed.

Moreover, the improvement of usability (e.g. improvement of the reactor availability-factor, shortening of the turnaround time, achievement of the attractive irradiation cost, establishment of the satisfied technical support system, retention of the business confidence) is under discussion taking account of the user’s comments/opinion.

After reoperation from FY 2011, the JMTR will be utilized fully by wide fields of users from national institutes, universities, industries as well as research group in JAEA. Moreover, the JMTR will also contribute the promotion on research and development of the nuclear energy from basic to applied fields as an internationally utilized facility under international/Asian network collaborations.

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Table 1 Major specifications of JMTR

Reactor Power	50 MWt
Fast Neutron Flux (Max)	4×10^{18} n／m^2・s
Thermal Neutron Flux (Max)	4×10^{18} n／m^2・s
Flow of Primary Coolant	6000 m^3／h
Coolant Temperature	49℃／56℃
Core Height	750㎜
Fuel	Plate type, 19.8% ^{235}U
Irradiation Capability (Max)	60 (20*) capsules
Fluence/y (Max)	3×10^{25} n／m^2・y
dpa of Stainless Steel (Max)	4 dpa
Diameter of Capsule	30 - 65mm
Temp. Control (Max)	2000℃

＊: capsule with in-situ measurement

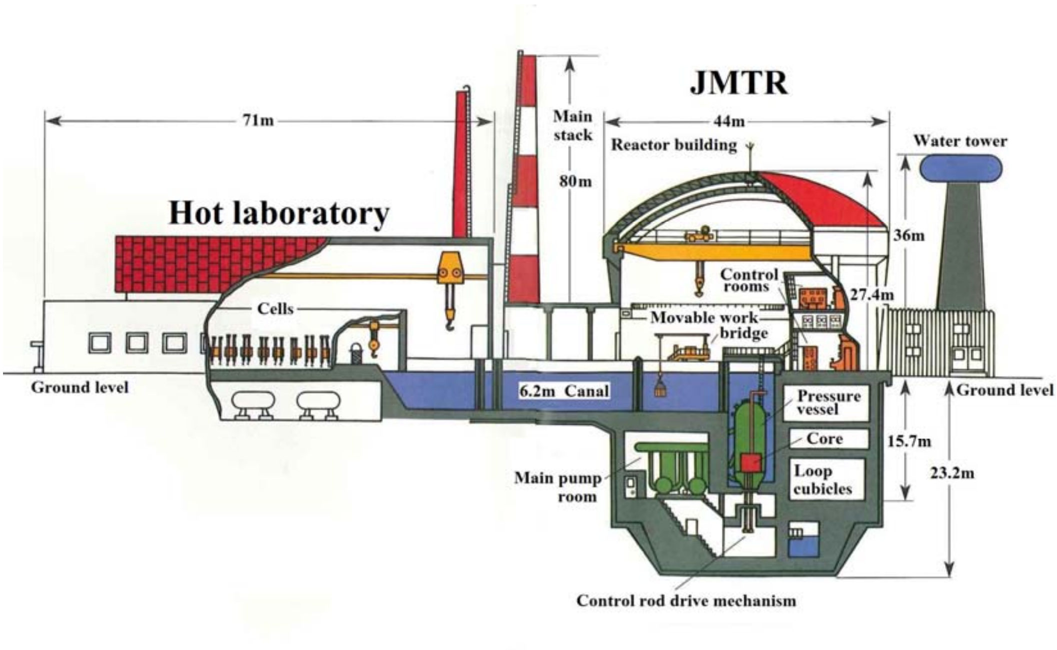

Fig.1 Cross section of JMTR and hot laboratory.

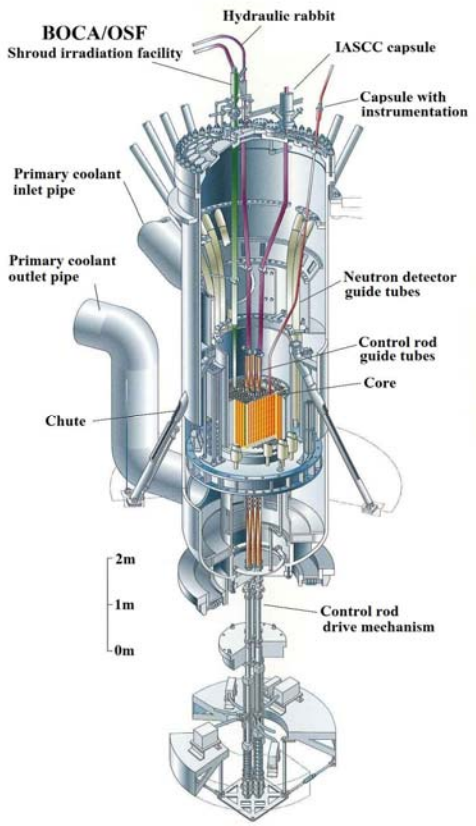

Fig.2 Cutaway view of reactor.

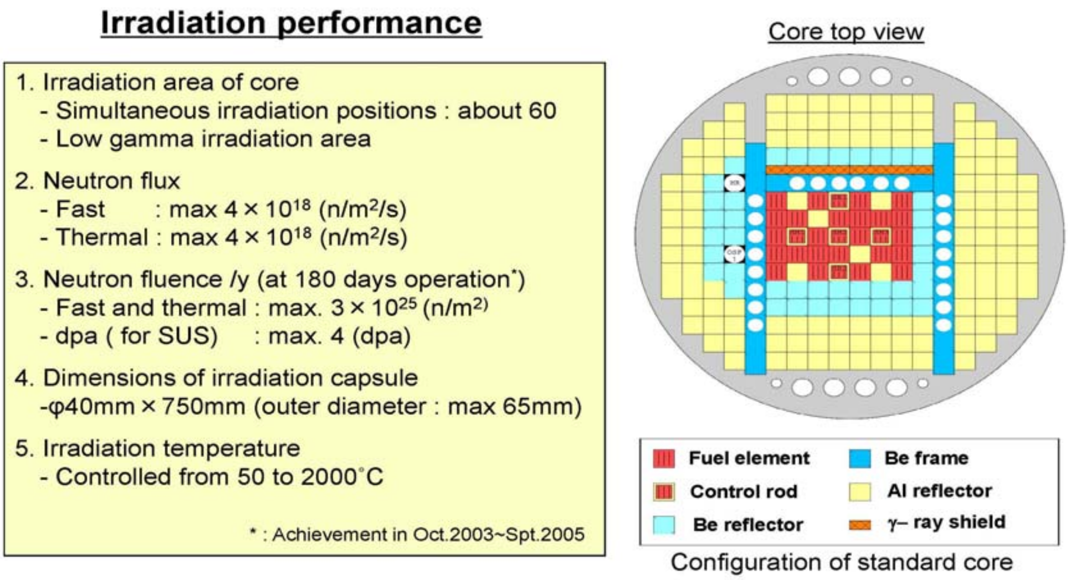

Fig.3 Irradiation performance of JMTR.

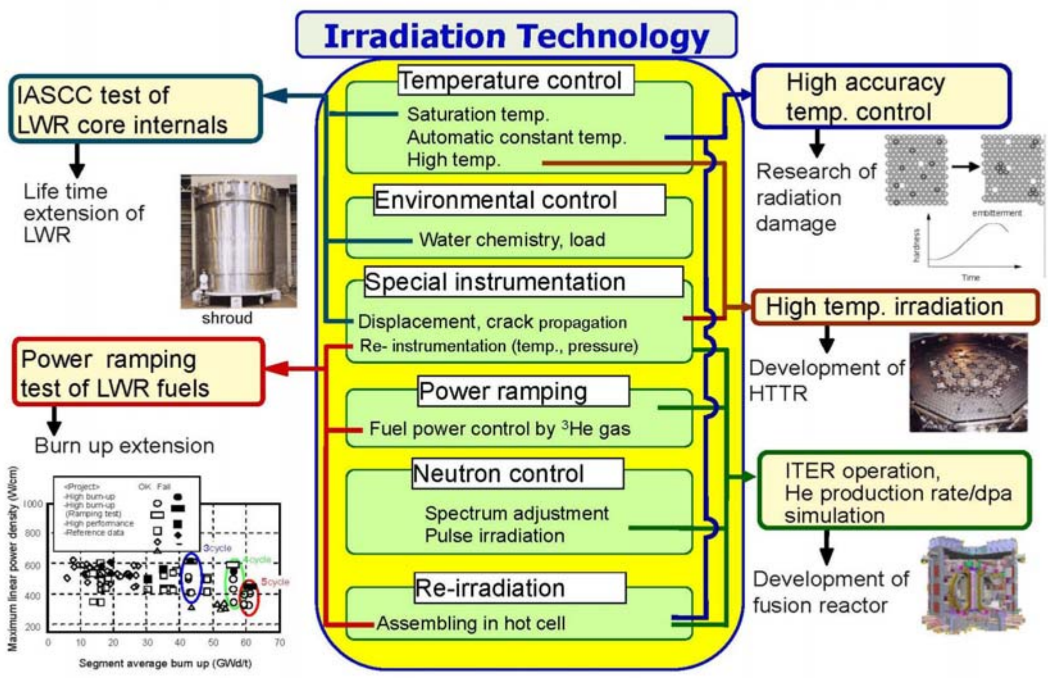

Fig.4 Applicable irradiation technology of JMTR.

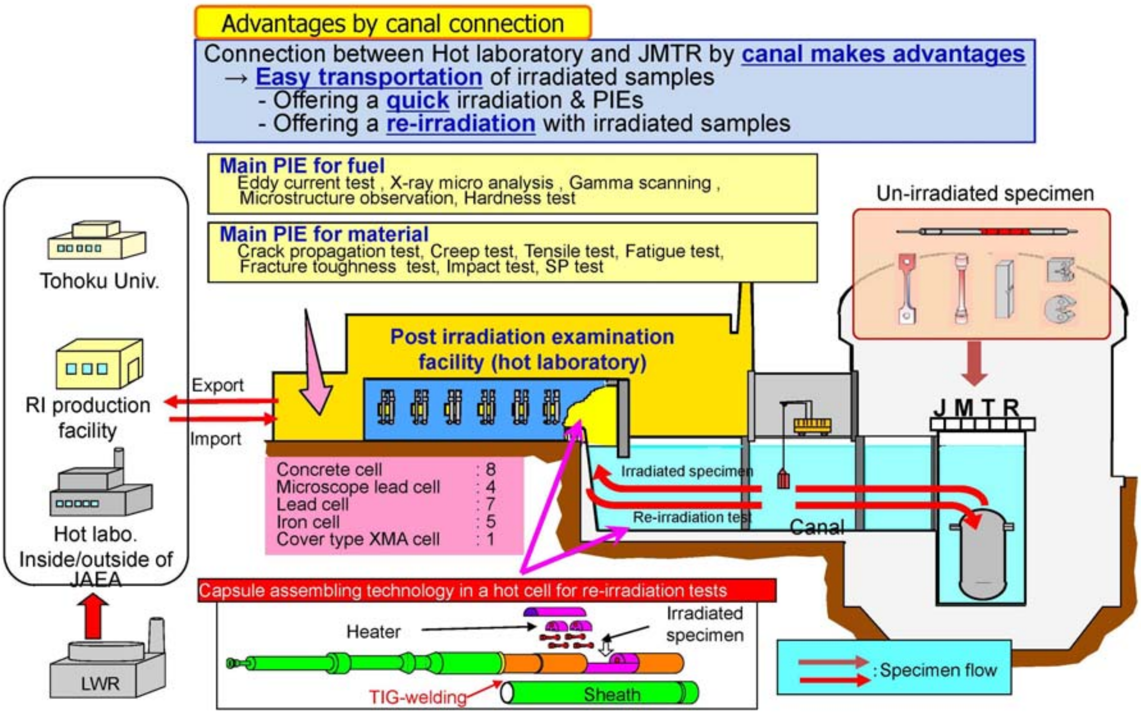

Fig.5 Possible post irradiation experiments of JMTR Hot Laboratory.

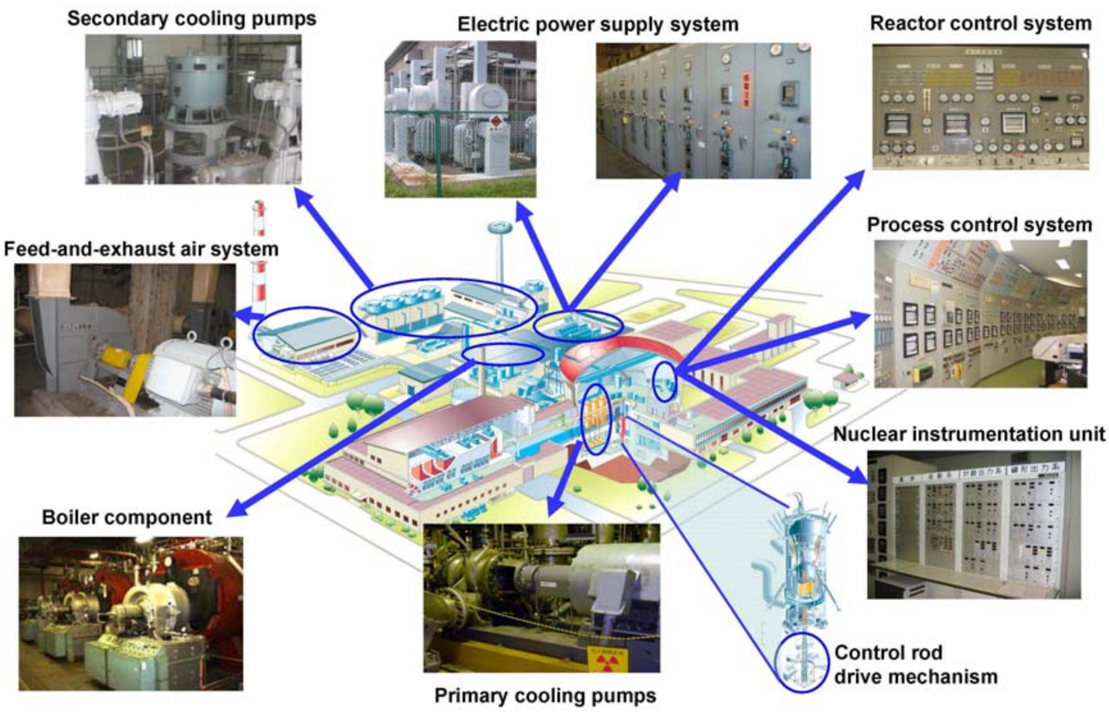

Fig.6 Replacement of reactor components.

Fig.7 Replacement schedule for reactor components.

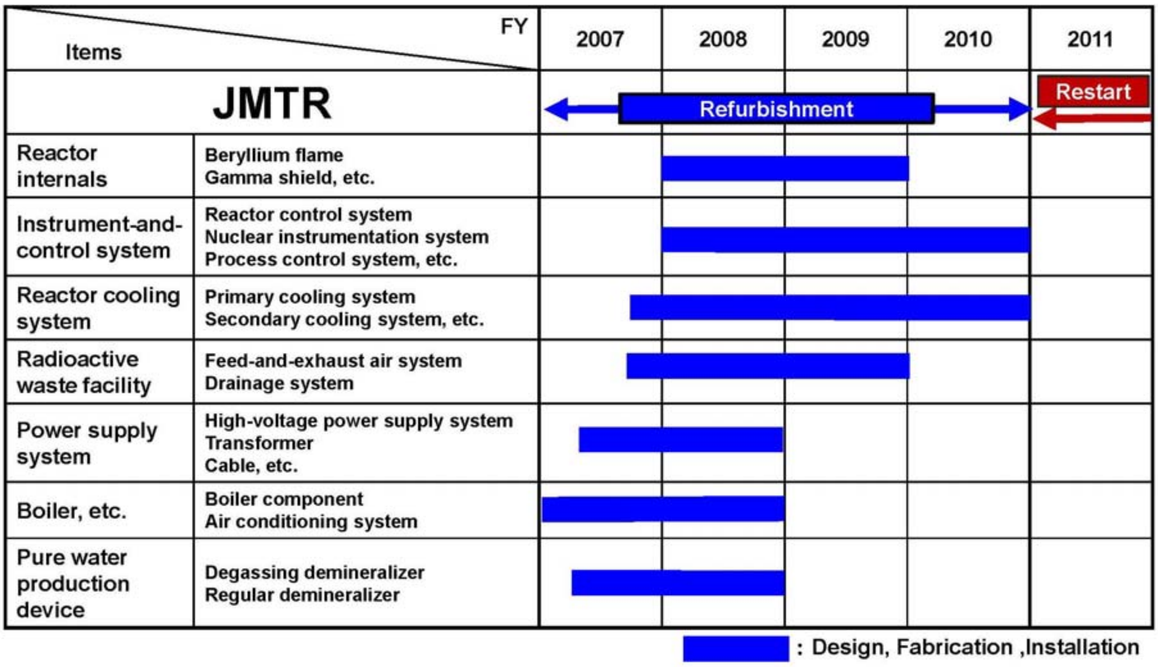

Fig.8 Preparation schedule for irradiation facilities.