# Present Status of Operation and Maintenance of JRR-3

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## I INTRODUCTION

The JRR-3(Japan Research Reactor No.3) was constructed as the first domestic reactor in 1962. The large-scale modification such as removal and re-installation of the core was carried out from 1985 to 1990. This paper describes the operation and maintenances of the JRR-3 during the last 20 years.

Following three topics are picked up as major maintenances; modification of fuel elements from aluminide to silicide, replacement of a process control computer system, replacement of a helium compressor of the helium gas system which is part of the heavy water cooling system.

The 20wt%-enriched-fuel was converted from aluminide to silicide in 1998 in order to utilize the fuel more efficiently.

The process control computer system monitors and controls various process values such as temperature, pressure and so on. In recent years, it is difficult to obtain main replacement parts because the computer system has been used for more 15 years. Therefore replacement the computer system has been carried out step-by-step since 2006.

Helium gas is used as covered gas for heavy water in the tank. The role of helium gas system is to recombine deuterium and oxygen. The system had troubles sometime, for example leakage of sealant in the helium compressor. The helium compressor was replaced in 2007.

## II Outline of JRR-3

The modified JRR-3 with the thermal output of 20MW is a light water moderated and cooled, swimming pool type research reactor. Heavy water and beryllium are used as reflector. The JRR-3 is composed of a reactor building, an experimental building, and a cooling tower. The reactor building is cylindrical construction of about 37m in height and about 32m in inside diameter. The reactor pool, canal, the spent fuel pool and so on are installed in the reactor building. The core is installed at the bottom of the reactor pool. The reactor pool is cylindrical pool with about 4.5m in diameter and about 8 m in depth. The specification of the reactor is shown in Table.1. A bird's-eye view of JRR-3 is shown in Fig.1.

Table.1 Specification of JRR-3

| | |
|---|---|
| Type | Low-Enriched-Uranium, Light-Water-Moderated and-Cooled, Pool Type |
| Thermal Power | 20MW |
| Reactor Core | Cylindrical type<br>Diameter approx.60cm<br>Height approx.75cm |
| Number of Fuel Element | Standard Type : 26<br>Follower Type : 6 |
| Control Rod Absorber | Hafnium (Box Type) |
| Experimental Facility | Horizontal Holes : 9<br>Vertical Holes : 17<br>Cold Neutron Facility : 1 |

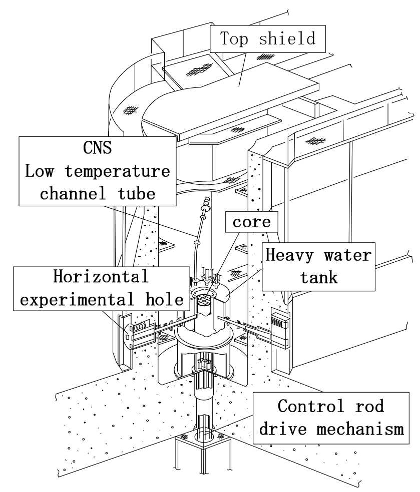


Fig.1 Bird's-eye view of JRR-3

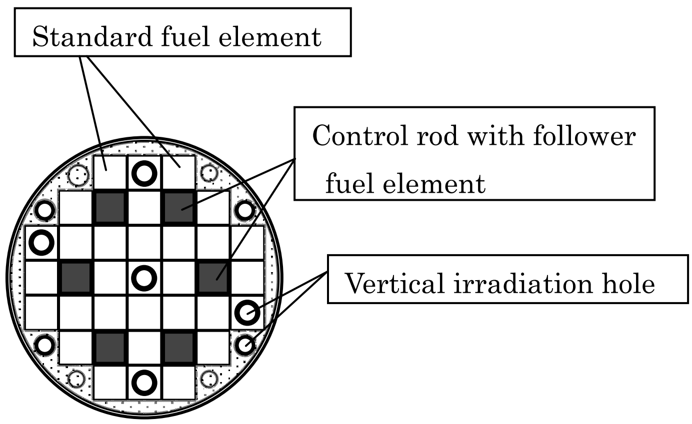


Fig.2 Core configuration

The core is composed of 26 standard fuel elements, 6 control rods with a follower fuel, beryllium reflectors and vertical irradiation holes. The core is surrounded by a heavy water tank. The heavy water in the tank is reflector and moderator, so it can change fast neutron to thermal neutron. The horizontal experiment hole and the vertical irradiation cylinder are installed in the heavy water tank. Fig.2 shows the core configuration.

The JRR-3 is operated normally at seven operation cycles a year. One cycle basically consists of 4 weeks of operation with the rated power and 1 week of shut down for refueling, irradiation capsule handling and maintenance works. It reached integrated output of 59.9GWd in July, 2009. Fig.3 shows the annual operating time of the JRR-3.

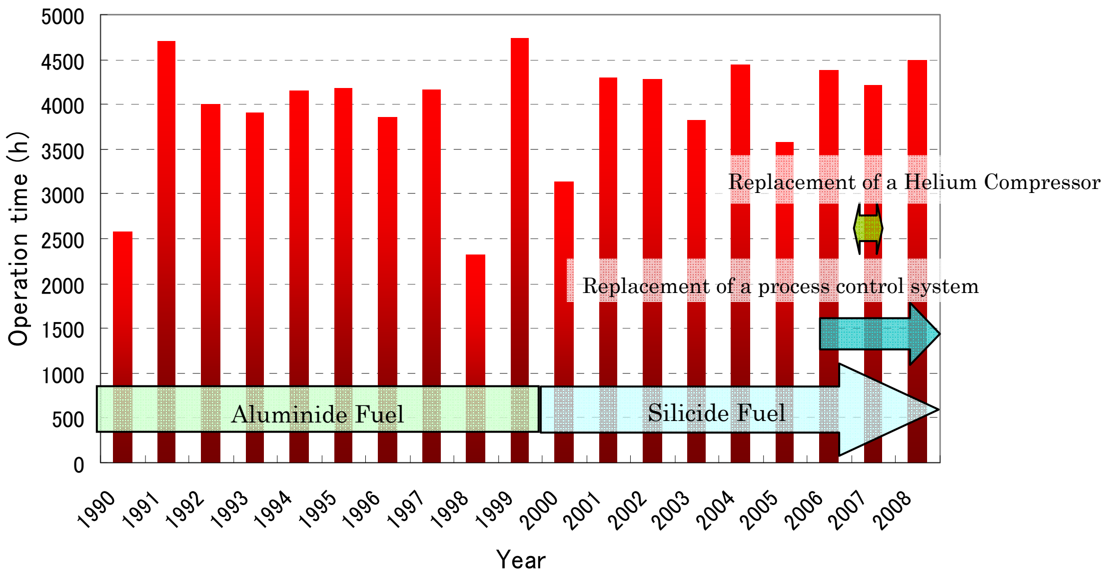


Fig.3 Annual operating time (h)

## Ⅲ Modification of fuel elements

In recent years, the reactor fuel for research reactors has been modified from the aluminaid fuel (U-Al ) to the silicide fuel ($U_3Si_2$-Al ). The silicide fuel is adopted in JRR-3 since 2000. With the conversion uranium density was increased from 2.2 to 4.8 g/cm$^3$ keeping uranium-235 enrichment of 20%. So, burnable absorbers (cadmium wire) were introduced for decreasing excess reactivity caused by the increasing of uranium density. With the conversion, the limit of fuel burn-up was increased from 50% to 60%. And the fuel exchange procedure was changed from the six-batch dispersion procedure to the fuel burn-up management procedure.

The standard fuel element is composed of 21 fuel plates, and the follower fuel element is composed of 17 fuel plates. Table.2 shows the comparison between silicide fuel element and aluminide fuel element. Fig.4 shows the externals of silicide fuel element.

Table.2 Comparison between silicide fuel element and aluminide fuel element

| Item | Aluminide | Silicide |
|---|---|---|
| Size[mm] | 76×76×1150 | |
| U-235 Enrichment[wt%] | 20 | |
| Uranium Density[g/cm$^3$] | 2.2 | 4.8 |
| U-235 Content[g] | 300 | 470 |
| Clad Material | Aluminum alloy | |
| Maximum Burnup[%] | 50 | 60 |
| Burnable Absorber | | Cadmium |

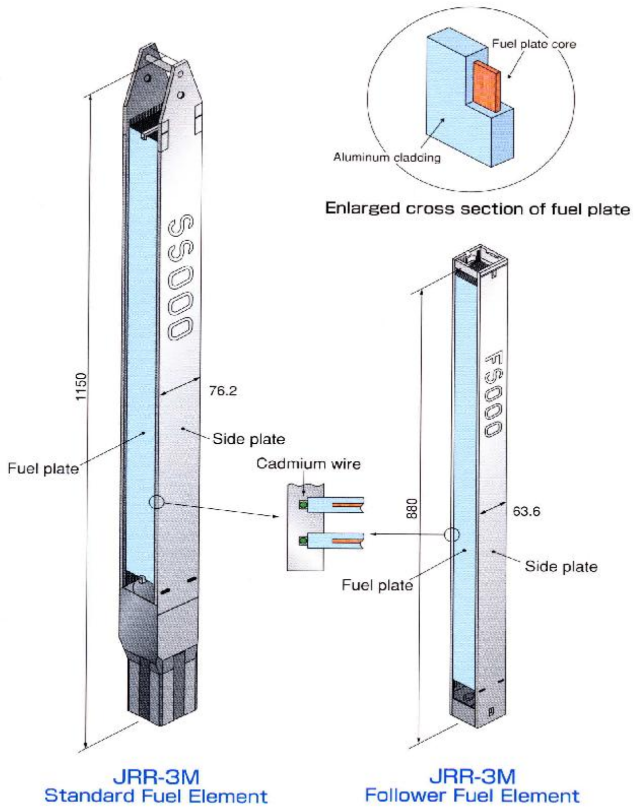


Fig.4 Externals of silicide fuel element

## Ⅳ Replacement of the process control computer system

The process control computer system monitors and controls various process values (approx. 5000 values) such as temperature, pressure and so on. All process values can be monitored at the control room by using this system. The computer system is composed of control computers, I/O cards, bus lines and operation terminals.

In recent years, it is difficult to obtain main replacement parts because the computer system has been used for more 15 years. Therefore replacement of the computer system has been carried out step-by-step. Replacement of the computer system has three stages. Just now, the 1st and 2nd stages had been completed. The contents of the replacement works from the 1st stage to the 3rd stage are shown in the following.

- The 1st stage・・・Replacement of operation terminals. (These are used for indication of process values and operation of equipments)
- The 2nd stage・・・①Replacement of control computers.(These are used for control and measurement of local equipments.)
  ②Replacement of bus lines (Bus lines are changed from HF bus to V net. Both communication methods are exclusive for manufacturer.)
- The 3rd stage・・・Replacement of I/O cards(These are used for input process values from equipments such as detectors and output signals to equipments such as pumps.)

Fig. 5 shows the configuration diagram of the process control computer system before the replacement. Fig.6 shows the process control computer system after the replacement.

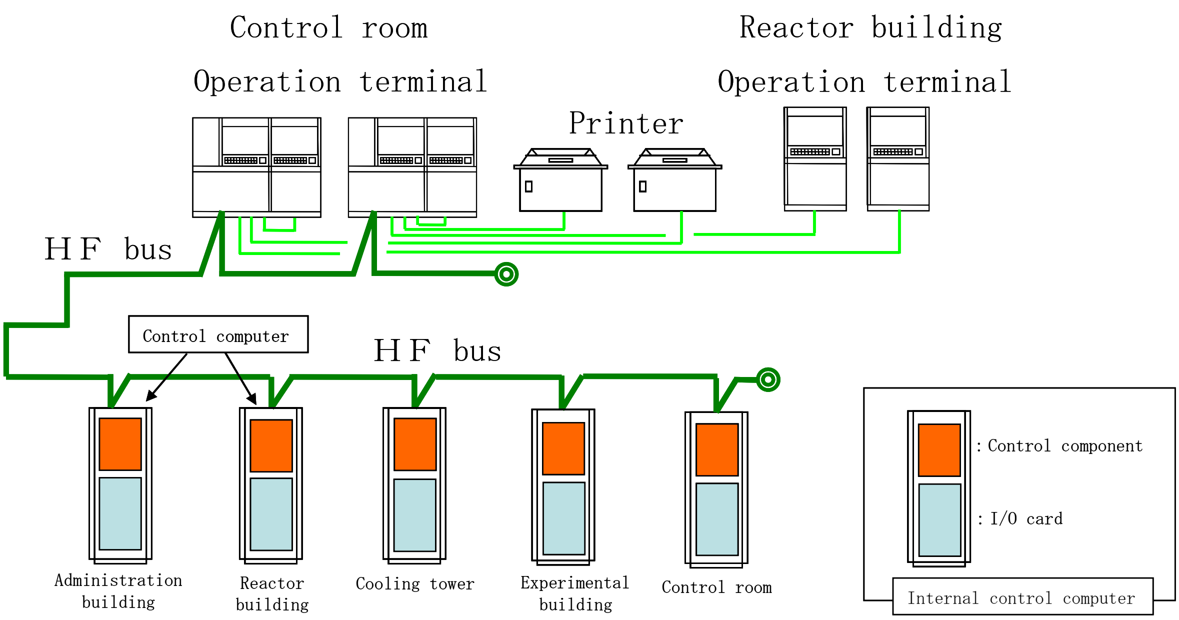


Fig.5 Configuration diagram of the process control computer system before the replacement

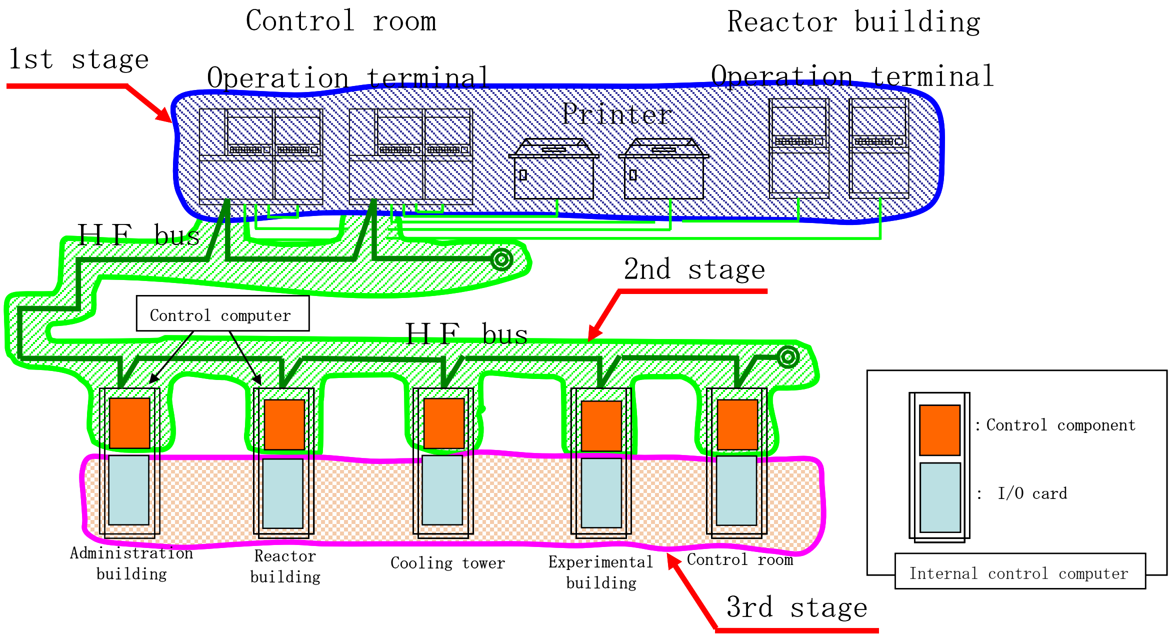


Fig.6 Process control computer system after the replacement

The replaced process control system at the first stage and second stage has general purpose properties. Therefore, the operators can improved the graphics screen themselves to improve operability. The operation screen is scheduled to be improved in the future. The renewals of the operation terminal and the FCS key components of the process control system were almost completed by the update work up to the second stage. The replacement of I/O cards in FCS and TBC is scheduled to be done as replacement in the third stage in the future.

## V Replacement of a helium compressor of the heavy water cooling system

The heavy water tank surrounds the reactor core to use neutron which generated in the reactor core for experiments efficiently. The heavy water cooling system removes the heat generated in the heavy water reflector by gamma heating. The heavy water cooling system is composed of the cooling system and the helium gas system. The helium gas system has an important role of helium gas circulation. The helium gas system also has role to recombine deuterium and oxygen. The helium gas system is composed of the helium compressors, the helium condensers, the helium recombinator, the helium tank, and piping. We have been overhauling the helium compressors regularly and replacing consumable parts. However, in recent year, automatic shutdown of the helium compressor sometimes occurred by the leakage of the seal oil. The helium compressor was replaced in 2007. The helium compressor makes helium gas circulate with the vertical movement of the piston in the cylinder.

The helium gas system contains tritium because tritium gas is generated in the heavy water tank by neutron irradiation to deuterium. The helium compressor has seal oil which is enclosed within "distance-piece" between the "crankcase" and cylinder so as not to leak helium gas to the atmosphere. If the seal oil leaks, tritium gas should be released. Therefore, the helium compressor automatic shutdown when the seal oil level is decreasing to the certain level. The construction drawing of the helium compressor is shown in Fig.7. Fig.8 shows the system diagram of the helium gas system.

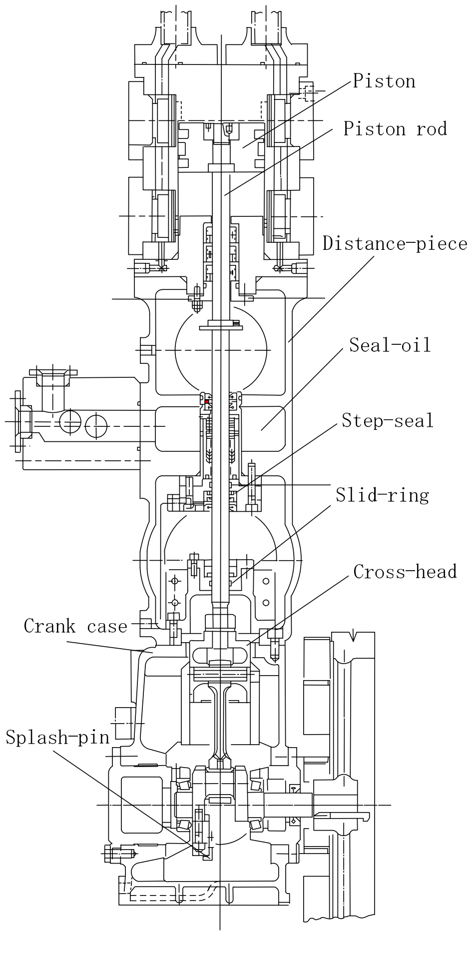


Fig.7 Construction drawing of helium compressor

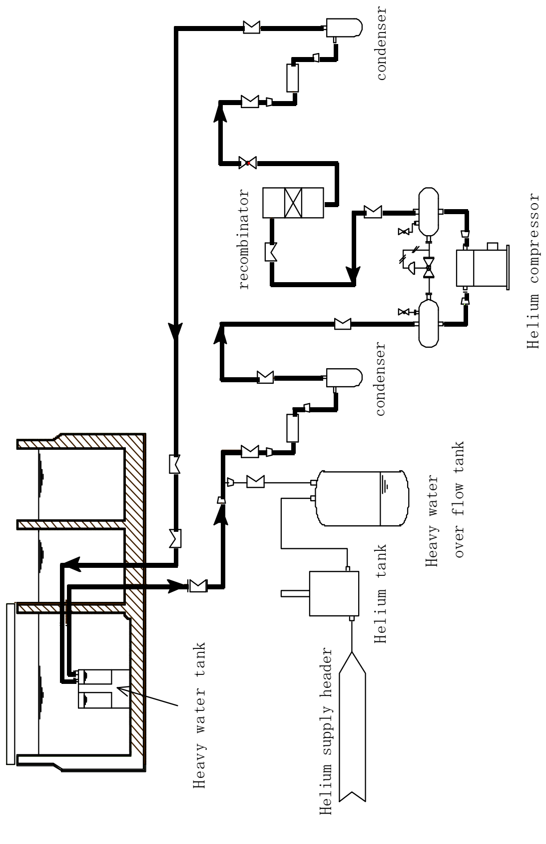


Fig.8 Helium gas system diagram

The various modifications were done on the basis of a past problem.

Major improvements are as follows;

- Doubling of "step-seal"

  Increased the number of "step-seal" which has the role that not to leak the seal oil.

- Addition of a new part

  Add the part which name "slid-ring". "Slid-ring" has the role that not to abrasion of "step-seal".

- Change of part design

  We changed the design of the part which is named "cross-head". By changing the design, we enable to resolution check more surely and easier.

- Change of part shape

  We changed the shape of the part which is named "splash-pin". By changing the shape, more lubricating oil is supplied and the life of the part is prolonged.

- The increase of the warning system

  We increase the number of warning switch of oil liquid level indicator. By increasing it, we detected seal oil decreasing at the early stage.

## Ⅵ CONCLUSION

JRR-3 has continued the stable operation with several maintenances such as the upgrade of the fuel elements, the replacement of the process control computer system, and the replacement of the helium compressor, and so on, as described in this paper.