FUEL ELEMENT REPLACEMENT AND COOLING WATER RADIOACTIVITY AT THE MUSASHI REACTOR

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Abstract

The Musashi reactor (TRIGA-II, 100kW) has been operated without any serious troubles since 1963. In 1985 the old Al-cladded fuel elements were replaced with new stainless cladded ones in order to insure a long and safe operation.

By using a semi-automatic equipment the old fuel elements have been transferred into the bulk-shielding experimental pool, which was remodelled for the spent-fuel storage. In order to reduce the exposure during the transfer work, the old fuel elements were cooled in the core tank for 3 months.

After the replacement, the radioactivities in the cooling water have been drastically changed. The activity of Na-24 decreased about one decade, and the activities of Cr-51, Mn-54, Mn-56, Co-58 and Co-60 increased about two decades.

At this conference we will report on the following points:

(1) semi-automatic equipment for the transportation of the Al-cladded spent fuel,
(2) structure of spent-fuel storage pool, and
(3) radioactivity change in the cooling water.

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I Introduction

The Musashi Institute of Technology Research Reactor (TRIGA 11 100kW, the Musashi Reactor) has been operated without serious problems since 1963. The occasion arose, however, when we needed to choose one of the following three options, because there were no more spare fuel elements;
(1) to obtain some new aluminium cladded fuel elements and operate with both these and the old aluminium cladded ones,
(2) to obtain some stainless steel cladded standard fuel elements and operate with both those and the old aluminium cladded ones, and
(3) to obtain many stainless steel cladded fuel elements and operate with only those fuel elements.

Option (1) is the easiest way of obtaining operating permission from the regulating agency (the Science and Technology Agency) of the Japanese Government. Option (2) have often been adopted in the case of other old TRIGA reactors around the world, but some difficulty in negotiating permission from the regulating agency was predicted by reason of the complex fuel arrangement in the core. Option (3) is the best from the technical point of view, for long-term, trouble-free operation, though it did require some negotiation with the regulating agency and it is the most expensive way.

In the end, we decided to adopt option (3) under the auspices of the Ministry of Education, Science and Culture of the Japanese Government.

The bulk shielding experimental pool was remodeled as storage for the spent fuel elements, where the neutrons from the thermalizing column were shielded by cadmium and boron-polyethylene plates. Equipment for transferring the spent fuel elements was built and temporarily set up between the core tank and new storage.

This work started in fall 1983 with the motion of the change of permission with the regulating agency of the Government, and finished in summer 1985 when the agency's permission to recommence operations was received.

After the reactor was restarted, the count-rate of the conventional cooling water monitor, which was set in the cooling system using a GM counter, drastically decreased as shown in Fig.1. Therefore the radioactivity in the cooling water was precisely surveyed again, as had been done in the time of the old core [1].

In this paper, we describe the spent fuel storage, the work of transferring the spent fuel elements and the cooling water activity.

II Fuel Element Replacement

2-1 Spent fuel storage

Figure 2 shows a vertical sectional view of the spent fuel storage and transfer equipment which was temporarily set up. The storage is composed of a storage pool and a storage tank which is made from stainless steel and sunk at the bottom of the storage pool, supported by a floating prevention supporter. The storage tank is composed of an inner tank and an outer lid as shown in Fig.3. The spent fuel elements are lined up cylindrically in three lines in a fuel stand in the inner tank (see Photo.1). Ninety spent fuel elements can be stored in this storage, and remain in a subcritical state under all conditions. The storage also has a purification system of water and a nitrogen gas system.

After the spent fuel elements were inserted in the holes in the inner tank and the lid was put on, nitrogen gas was supplied to the tank and water was excluded from the tank. Thus the spent fuel elements are stored in a nitrogen atmosphere in the bottom of the storage pool.

The purification system is shown in Fig.4. The system is composed of three subsystems: They are; (1) system for supplying purified water to the storage pool, (2) purification system for the pool water and (3) exhaust system for the pool water. If water has to be supplied to the pool, purified water is supplied from the supply system. The water is continuously circulated between the pool and the purifier and the conductivity is kept below 2μS/cm. Waste water is transferred to a waste water storage pit which has already been built for other radioactive waste water, and it is disposed of the other radioactive waste.

The nitrogen gas system supplies the nitrogen gas from a gas cylinder to the storage tank and the nitrogen gas is exhausted through the stack of the reactor building when the tank is opened.

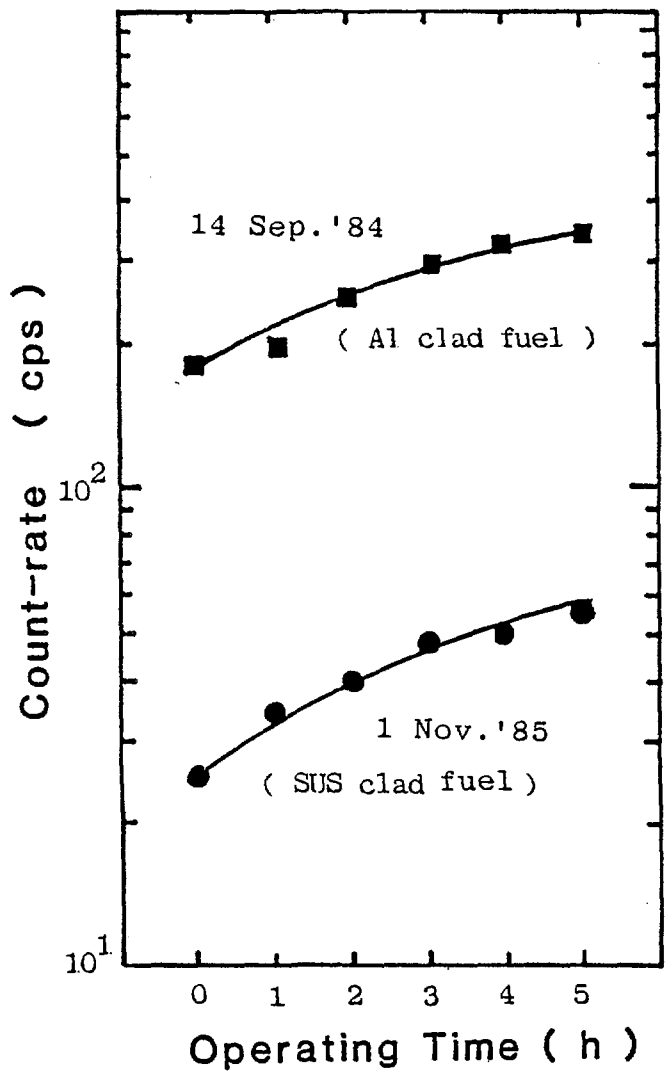

Fig.1 Change in count-rate of water monitor.

Fuel transfer equipment

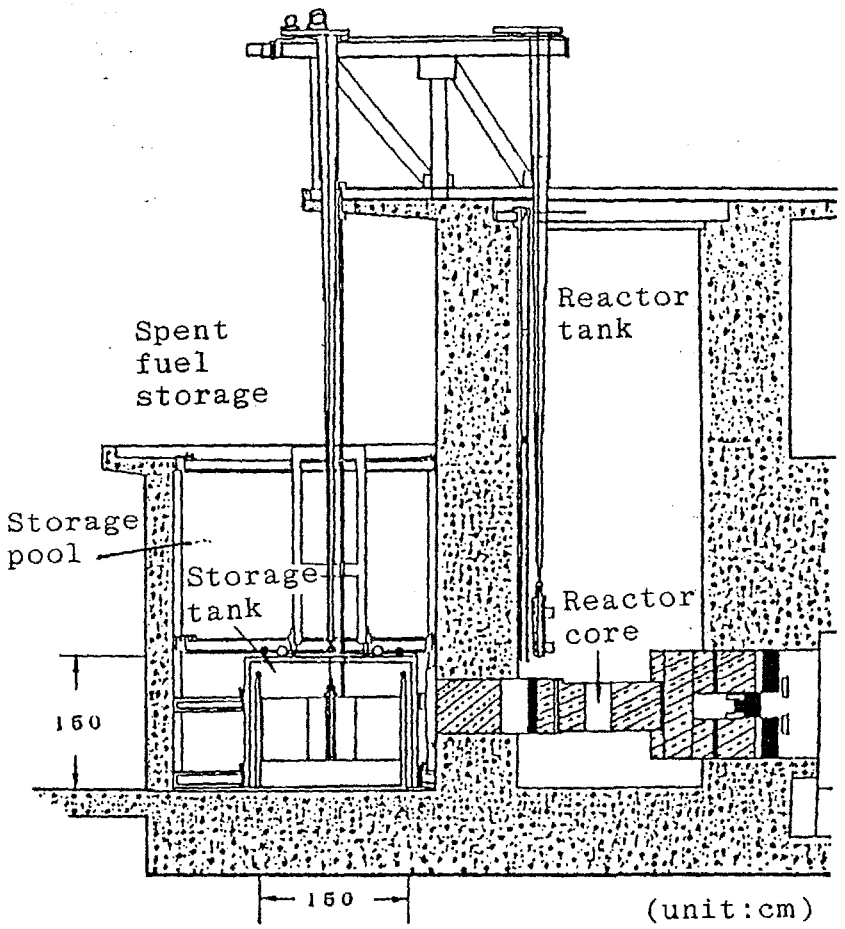

Fig.2 Vertical sectional view of reactor core and spent fuel storage.
--Fuel transfer equipment is assembled between core and storage--

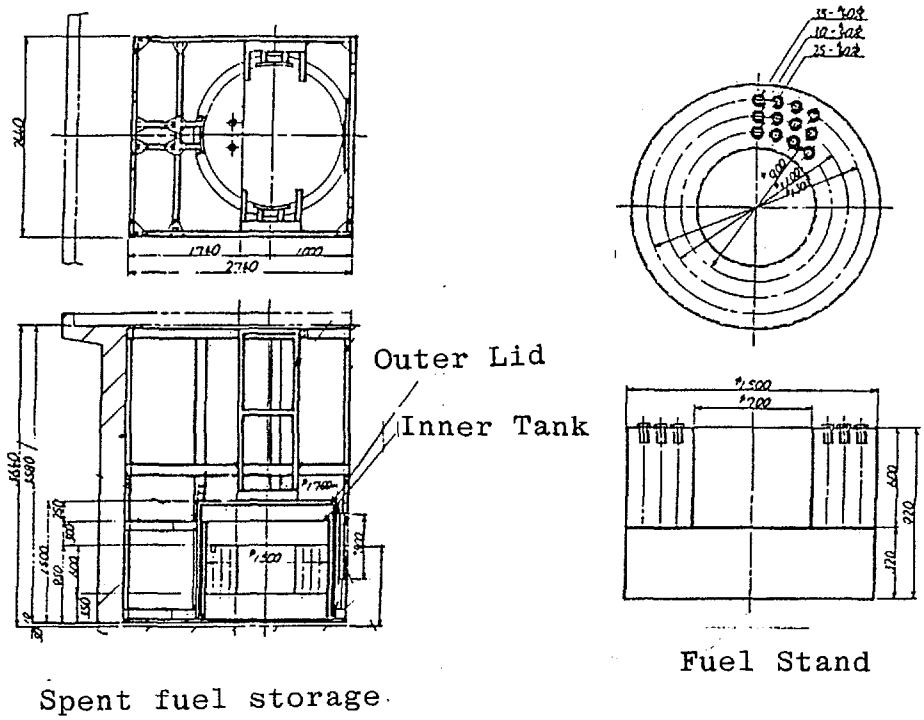

Fig.3 Spent fuel storage and fuel stand in inner tank.

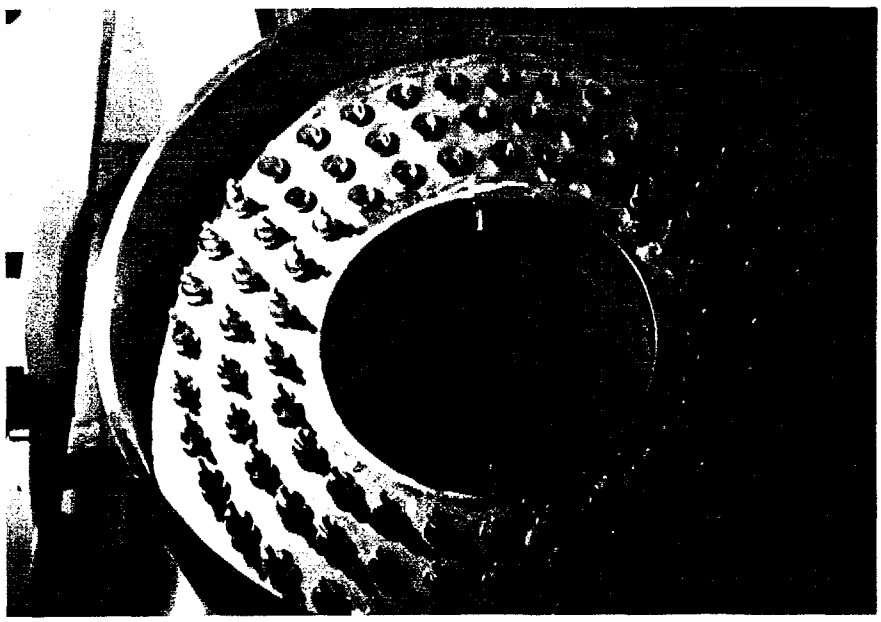

Photo.1 Opened inner tank storing the fuel elements

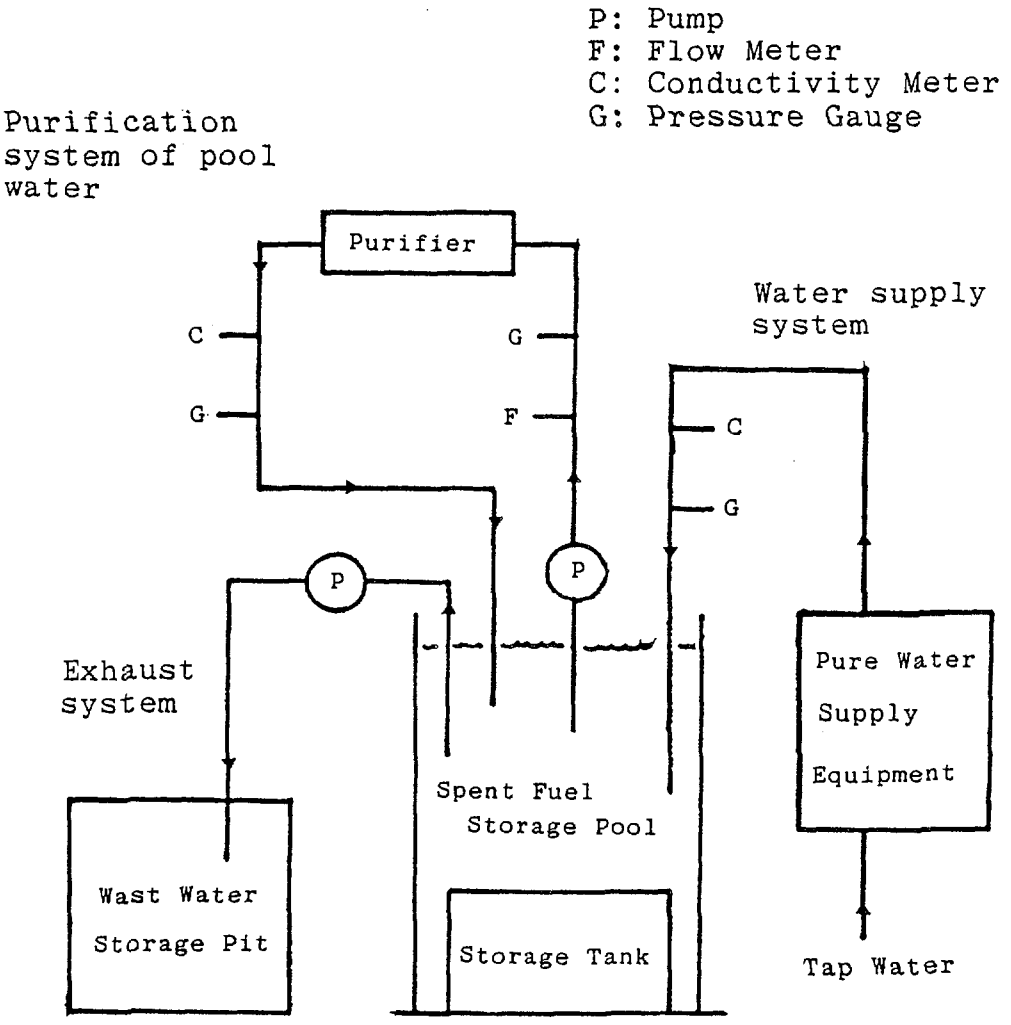

Fig.4 Conceptional design of purification system.

2-2 Equipment and work for fuel transfer

The spent fuel elements were transferred after a cooling period of about three months. The radioactivity was about 370 GBq for each fuel element. This value shows that the fuel elements can be transferred easily using a relatively simple and thin shielding capsule with low personnel exposure. We, however, preferred another more reliable and safe way with which even lower personnel exposure was to be expected.

A vertical view of the transfer equipment is shown in Fig.5. The spent fuels are semi-automatically transferred from the reactor tank through the reactor top to the new spent fuel storage. In Fig.5 the one movable part of the equipment is described as part of both sides, the reactor core tank and the storage, as if it were in the two parts.

The transfer work was performed as follows:
(1) The fuel element was manually pulled out of the core using a conventional fuel-handling tool for the TRIGA reactor, and inserted into a fuel case in the transfer equipment ((1) in Fig.5),
(2) The case was put into the lower edge of expansion and contraction rod ((2) in Fig.5) by using the swing handle which is fixed at the reactor top ((3) in Fig.5),
(3) After step (2) was completed, the workers left the reactor hall in order to operate the equipment remotely and avoid unexpected radiation exposure.
(4) After all persons had left the reactor hall, the following operations were automatically performed by the pushing of a button;
1) the expansion and contraction rod was shortened and pulled up, then the case with the spent fuel also went up to the reactor top,
2) when the case in the expansion and contraction rod had arrived at the reactor top, the drift table which hang the rod with the case ((4) in Fig.5), was drifted to the storage side on the top,
3) when the expansion and contraction rod arrived at the storage side and the drift table stopped there, the expansion and contraction rod expanded farther and the case went down with the lower edge of the expansion and contraction rod,
4) when the case in the expansion and contraction rod arrived under the water at the center of the inner tank, the motion of the expansion and contraction rod stopped.
(5) After the signals on the operation panel and TV monitor confirmed that it had stopped, the workers went into the reactor hall again.
(6) The case was removed from the expansion and contraction rod by use of the swing handle ((5) in Fig.5).
(7) The fuel element was manually pulled out of the case using the fuel-handling tool and inserted in a hole in the inner tank.
(8) The case was again put in the expansion and contraction rod and it was returned to the reactor tank by remote control.

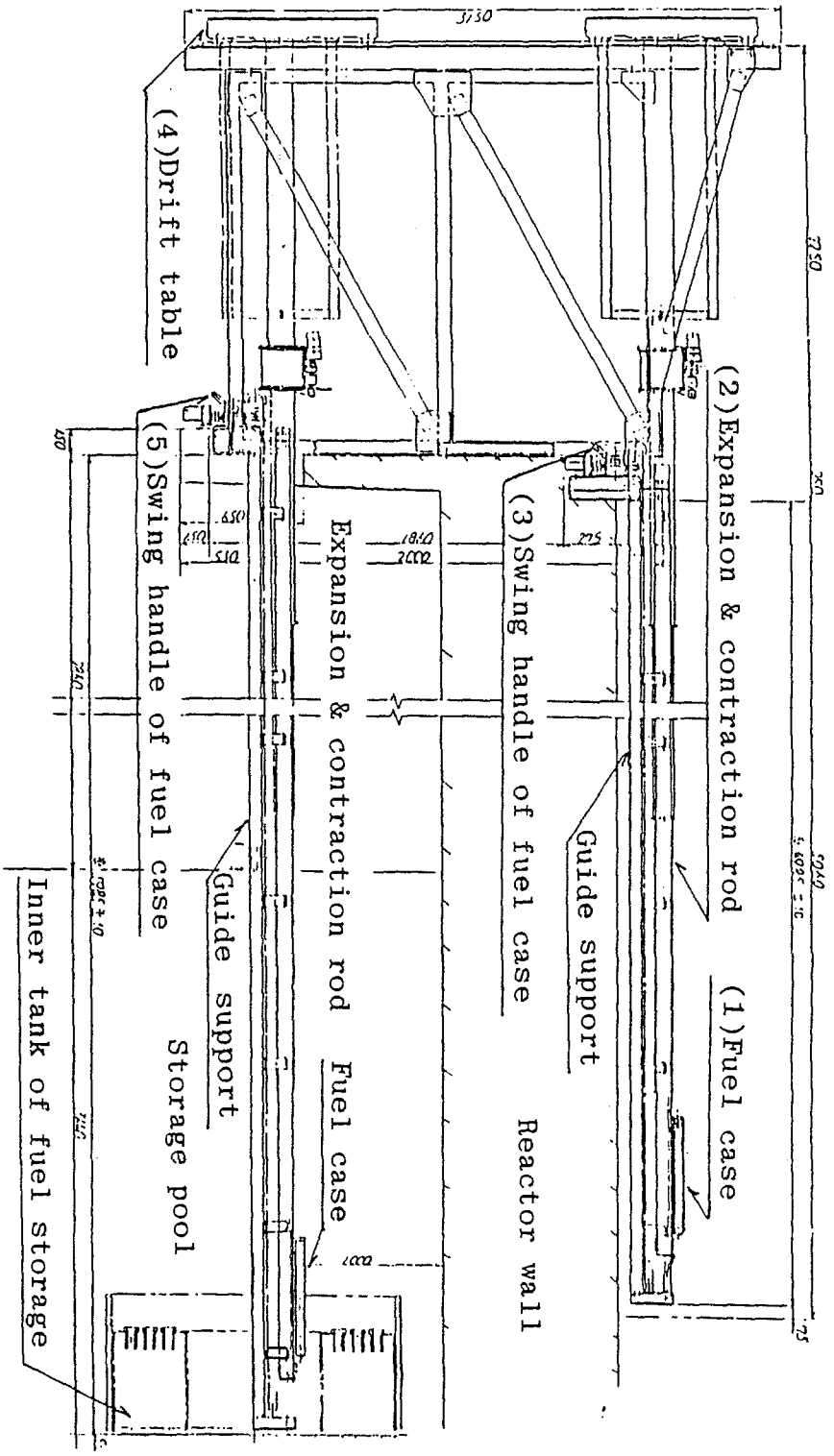

Fig.5 Fuel transfer equipment.

The transfer of one element took about 20 minutes. These operations were repeated 65 times in 3 days. During the work, TLD at the reactor top recorded an exposure of 3.5 R but the workers' individual monitors did not show any exposure. After the work, the equipment was removed.

III Cooling Water Radioactivity

As shown in Fig.1, the count-rate of the cooling water monitor much decreased. We, therefore, surveyed the radioactivity in the cooling water by the method used before the replacement, and the results were compared as the cases before and after the replacement.

3-1 Method of radioactivity measurement

Anion or cation ionexchange resin of about 80 cm^3 was used for the collection of radioactive nuclides in the cooling water. For the sampling, the cooling water was pumped up from about 2m depth below the top surface of the reactor tank at a flow rate of 13cm^3/s and it was passed through an ion exchange resin column of 80 cm^3 for about one hour. The collecting efficiency for each of Na-24, Te-99m, I-132, La-140 etc. in the sample was about 80%. Hence the value of 80% was used for each nuclide. The sampling was performed after the reactor shut-down on Friday, when the radioactive concentrations would be almost at their maximum. The measurement of radioactivity was carried out using a Ge(Li) gamma-ray spectrometer.

3-2 Cooling water radioactivity with the old and new cores

The change in radioactive concentration of various kinds of radioactive nuclides in the cooling water before and after the replacement is shown in Fig.6. The change from the old core to the new one is shown by the direction of the arrows. The values for the old core were measured on September 2 and 16, 1982 by use of cation and anion exchange resin, respectively, and the mean values of three cases measured between April and November, 1986 are used for the new core. There was almost no change in the values for the new core in 1987.

The radioactive concentration of Na-24 decreased by about one order of magnitiude after the replacement. This change can easily be understood as being caused by the replacement, which resulted in a decrease in the amount of aluminium in the core, because the nuclide Na-24 was mainly produced by the reaction $^{27}Al(n,\alpha)^{24}Na$.

Otherwise, the radioactive concentrations of such nuclides as Cr-51, Mn-54, Mn-56, Co-58 and Co-60 increased by about two order of magnitude. The new cladding material SUS 304 includes chromium (18.3%), nickel (8.7%), manganese (1.8%) and maybe also a small amount of cobalt. It is considered that the nuclides Cr-51, Mn-54, etc. mentioned above may have been produced by the following nuclear reactions:

Mn-54: $^{54}Fe(n,p)^{54}Mn$,

Mn-56: $^{55}Mn(n,\gamma)^{56}Mn$, $^{56}Fe(n,p)^{56}Mn$,

Cr-51: $^{50}Cr(n,\gamma)^{51}Cr$,

Co-58: $^{58}Ni(n,p)^{58}Co$,

Co-60: $^{59}Co(n,\gamma)^{60}Co$, $^{60}Ni(n,p)^{60}Co$.

From these results, it can be concluded that the cladding material is the main source of many radioactive nuclides in the cooling water of the Musashi reactor.

Fission products such as I-132, I-133, Te-133 etc. were also detected. The change in concentration between the old and new cores is not large. It decreased to about one-half as shown in Fig.6. A small amount of fission products could be produced from trace amounts of uranium in or on the core components, coming into contact with the cooling water in some kinds of research reactor [1,2,4].

In order to have some data, the uranium content in the aluminum cladding of the graphite dummy element, which was made at the same time as the fuel elements, was measured and determined as 0.2 ppm by the neutron activation method [5]. Moreover, we could find little uranium content in the three kinds of SUS 304 using the fission track method. It is also reported that the values were 0.32-0.17ppm for the JMTR fuel cladding and the fuel side plates made from aluminium, and below 40 ppb for the SUS-304 of the core materials [4]. If the uranium content in the aluminium cladding of the fuel element is 0.2ppm, the same as that in the dummy element and that of the stainless steel cladding is below 40ppb, and if the contribution of the cladding to the fission products is large, a greater change in the radioactivity should occur. The results shown in Fig.6 may suggest that the fission products were released from the other unchanged core material including more uranium.

VI Conclusion

The replacement of the fuel elements was successfully performed without any problems. The replacement has meant that there are hopes for the future of the Musashi reactor.

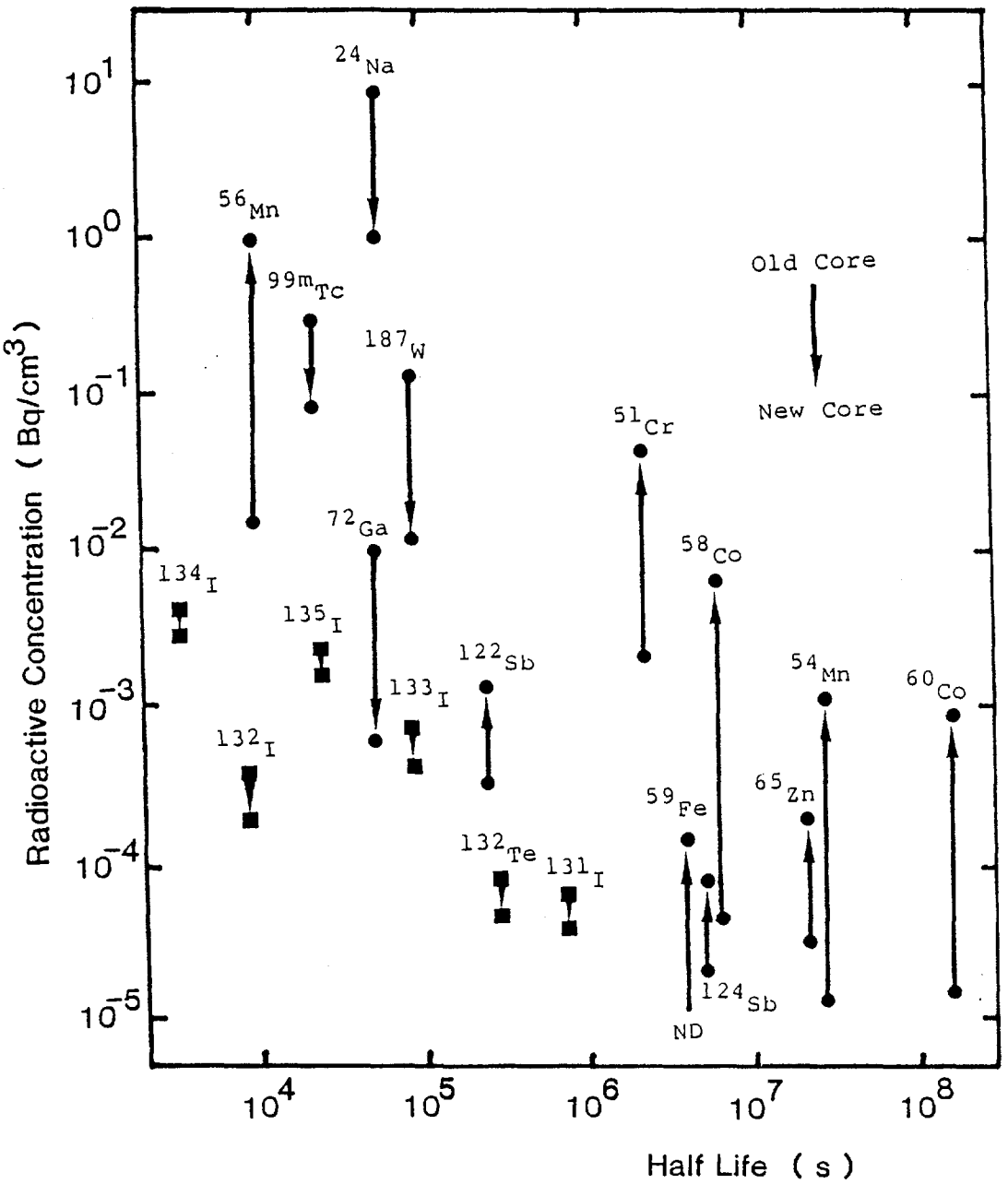

Fig.6 Change in the radioactive concentrations in the cooling water with replacement of the fuel elements.

● : Radionuclides (except for fission products)

■ : Fission products

ND: Not detected

Now we are looking forward to upgrading to 250kW. As well, the activity in the cooling water was measured and we found a clear difference in radioactive concentration between the cores with the aluminium cladded fuel elements and the stainless steel ones.

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