OPERATIONAL SAFETY AND REACTOR LIFE IMPROVEMENTS OF KYOTO UNIVERSITY REACTOR

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ABSTRACT

Recent important experiences on the operational safety and successful works for the operational life improvements of the reactor are described in the case of Kyoto University Reactor (KUR) of 25 years old 5 MW light water reactor provided by two kinds of thermal columns of graphite and heavy water as well as other various kinds of experimental facilities. In the graphite thermal column, noticeable amounts of neutron irradiation effects were accumulated in the graphite blocks near the core. Before the possible release of the stored energy, all the graphite blocks in the column were successfully replaced with new blocks at the chance of the installation of a liquid deuterium cold neutron source in the column. At the same time, special sealing mechanisms were also provided for the essential improvement on the problem of the radioactive argon produced in the column. In the other thermal column using heavy water, we have accomplished a successful repairing for a slow leakage of the heavy water through a thin instrumentation tube failure. The repairing work included the removals and reconstructions of the lead and graphite shielding layers and welding sealing of the instrumentaion tube under radiation fields. Several mechanical components in the reactor cooling system were also exchanged to new components with improved designs and materials. On-line data loggings of almost all instrumentation signals are continuously performed with a high speed data analyses system for the diagnosis of the operational conditions of the reactor. Furthermore, through detailed investigations on critical components, the operational safety for further extended reactor life will be supported by well scheduled maintenance programs.

1. INTRODUCTION

The Kyoto University Reactor (KUR, a light water moderated 5 MW reactor built in 1964) is widely used by researchers from universities and institutes in the whole over Japan, through the semiannual research application system. The structure of the reactor is provided by a graphite thermal column, a heavy water facility and 8 beam and exposure tubes. Figure 1 shows the vertical section of the reactor after the recent completion of the modernization program, which includes the insertion of a liquid deuterium cold neutron source and constructions of 6 neutron guide tubes (2 for thermal neutrons, 3 for cold and 1 for very cold neutrons). The present report describes recent important experiences on the operational safety and successful works for the reactor life improvements. A more detailed description on the performances of the cold source will be given in another contribution in the present Symposium.

2. MODIFICATION OF THE GRAPHITE THERMAL COLUMN

The graphite thermal column has been used long time for neutron beam experiments (for examples, the spectrum measurements of neutrons emerging from the graphite, neutron wave propagation experiments and also several neutron scattering experiments) as well as many irradiation experiments in the well thermalized neutron field. However, there were growing demands for the modernization of the column, especially for providing cold neutron source for a recent trend of the neutron beam experiments. In the irradiation aspects also, the original thermal column necessitates the shutdown of the reactor for the insertion and extraction of an irradiation sample, and therefore, they needed a more convenient irradiation device with a pneumatic system in the position of the high cadmium ratio.

An additional motivation for the modification of the column comes from the possible effects due to the accumulated neutron irradiations for the many years in the graphite blocks near the reactor core.

In our project, the graphite blocks in the column were completely replaced to new ones, and at the same time, the column structure was completely improved for the purpose to insert a cold neutron source accompanying cold and very cold neutron beam holes and a pneumatic irradiation tube, as shown in Fig. 2. According to the safety considerations in the design of the modified column, the new graphite column consists of a fixed and a movable portions, the former constructed in a tunnel-like feature and the latter assembled in a place outside the reactor to cover the complicated in-pile components of the cold source in conjunction with the shielding door, as shown in Fig. 3, and thereafter inserted into the former structure. Further, all the graphite blocks are connected each other by using connecting pins and rods for maintaining sufficient mechanical strength and seismic resistivity as the whole. As the results of the present safety considerations and methods, the modified column was completed with the minimized radiation leakage after the cold source insertion accompanying increased number of beam tubes.

Another important improvement is the sealing mechanism for minimizing the radioactive argon leakage produced in the column. The radioactive argon from the thermal column was the major contribution in the stack gas as well as the reactor room gas monitorings. Providing the specially designed sealing mechanisms for all of the penetrations and the beam windows in the column, and further the use of several stages of decay tanks, the contributions were significantly diminished after the completion of the new thermal column provided by a low flow-rate argon sweep line.

3. INSPECTIONS AND REPAIRING OF THE HEAVY WATER FACILITY

The heavy water facility of KUR is used mainly for thermal neutron irradiations under low epithermal neutron and gamma rays backgrounds, in biological researches and some medical studies such as neutron capture cancer therapy. In recent periodical inspections, however, a gradual increase of tritium contamination was noticed in the water of the sub-pool located opposite side to the heavy water facility in the reactor. After a number of detailed analyses of several records and investigations concerning the contamination distributions in the reactor room, we arrived the conclusion that the contamination should come from a slow leakage of the heavy water in the facility. Further efforts with the tritium monitoring following various changes of the heavy water level in the facility indicated the leakage spot to be a thin instrumentation tube for a thermocouple shown in Fig. 4.

A repairing program was decided to be four stage works consisting of i) removing the shielding components of the graphite and the lead layers in front of the heavy water tank, ii) cutting off the instrumentation flange at the middle portion of the nozzle and sealing the opening with a pin and welding, iii) decontaminations of the surrounding components, especially of the graphite layer containing a fraction of the escaped heavy water, and iv) reconstruction of the facility.

Before the start of these works, very careful estimations and several considerations for diminishing the radiation dose were carried out. One of the most effective ideas was the special preparation of an auxiliary shielding block of 15 cm thick iron completely fitting to the facility. The stainless steel bolts connecting the heavy water tank to the reactor core tank were also replaced to new ones before the welding works. Even after these precautions, the welding of the nozzle opening must be done under quite difficult conditions of very narrow space in considerable radiation field. Many times of rehearsals by the welder using a mock-up set of the same geometrical situations and the same materials led to the complete success of the welding passed the highest class examinations including penetration test and helium leak test.

The decontamination of the graphite layer was satisfactorily carried out for a long time baking process by enclosing the layer in a specially prepared air-tight vessel. Thereafter, the shielding components of the facility were completely reconstructed.

Temperature raising tests of the facility in the conditions of light water in the tank and thereafter of heavy water loading showed the complete tightness of the heavy water system. Further, repeated long time operations of the reactor at the full power level have now proven the final success of the repairing of the facility.

4. ADDITIONAL EXPERIENCES

In KUR, three heat exchangers are used for the cooling of the 5 MW thermal power. The heat exchanger in the original design consists of a soft steel shell and stainless steel tubes. After long time uses beyond 20 years, some kinds of corrosion phenomena brought a pin hole type failure in a narrow air-vent nozzle of soft steel portion containing the secondary water. Thereafter, these heat exchangers were replaced to those of all stainless steel type.

As one of the interesting phenomena accompanying continuous operations of the cooling system, apparent tendency of gradual enrichments of chlorine ions contained in the feed water is observed in the secondary coolant. Therefore, the concentration is carefully monitored before and after the periodical reactor operations.

In KUR, they have a many years research experiences of the reactor noise analyses related to the safety studies. Based on such a history, a computer system for the on-line data loggings of almost all reactor operation parameters such as neutron flux, control rods positions, coolant flow rates, coolant temperatures and so on have been accumulated, and these data are analysed with various kinds of statistical approaches.

5. CONCLUDING REMARKS

Through these recent experiences on the reactor safety and operational life improvements, we noticed again the importance of many years experiences of the reactor operation and maintenances including overhauls and components replacements as well as the accumulations of the research activities by the staff in the fields of reactor engineering and nuclear technology. A continuous efforts for the safety and the system improvements will be essential for the effective existences of the research reactor facility.

Acknowledgement

The most of the difficult works for the heavy water thermal column described in the present paper were carried out by the tight and direct collaborations of the staff of many related divisions in the Research Reactor Institute. The highest skill welding of the instrumentation tube was performed by the original manufacturer of the facility, Hitachi Manufacturing Company, Ltd.

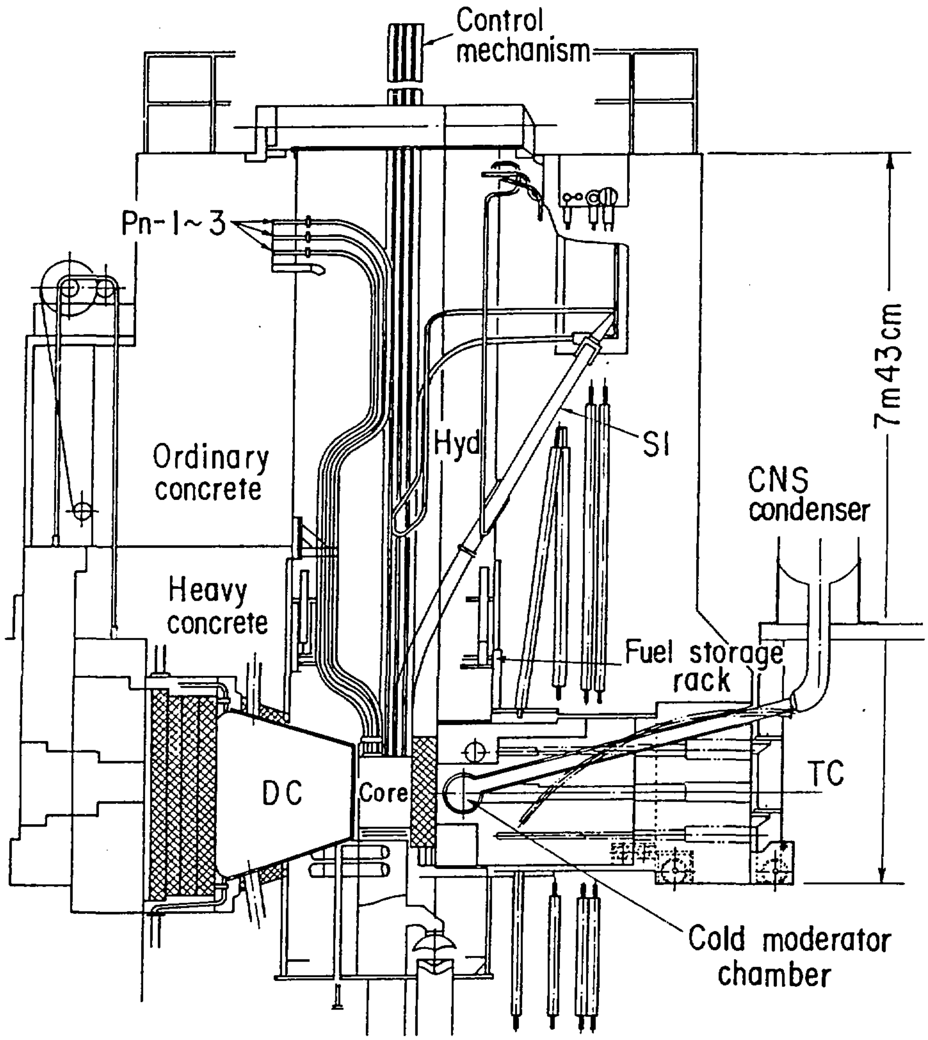
FIGURE CAPTIONS

Fig. 1 : Vertical section of KUR

Fig. 2 : Vertical section and plan of the modernized graphite thermal column

Fig. 3 : Movable graphite assembly including the cold neutron source and connected with the shielding door

Fig. 4 : Heavy water tank of the facility showing the repairing portion



DC	Heavy Water Facility
TC(CNS)	Graphite Thermal Column, Cold Neutron Source
Pn-1~3	Pneumatic Tubes
SI	Slant Exposure Tube
Hyd	Hydraulic Conveyor Tube

Experimental facilities of KUR
(vertical cross section)

SM-310/110P, Fig. 1 (M. Utsuro)

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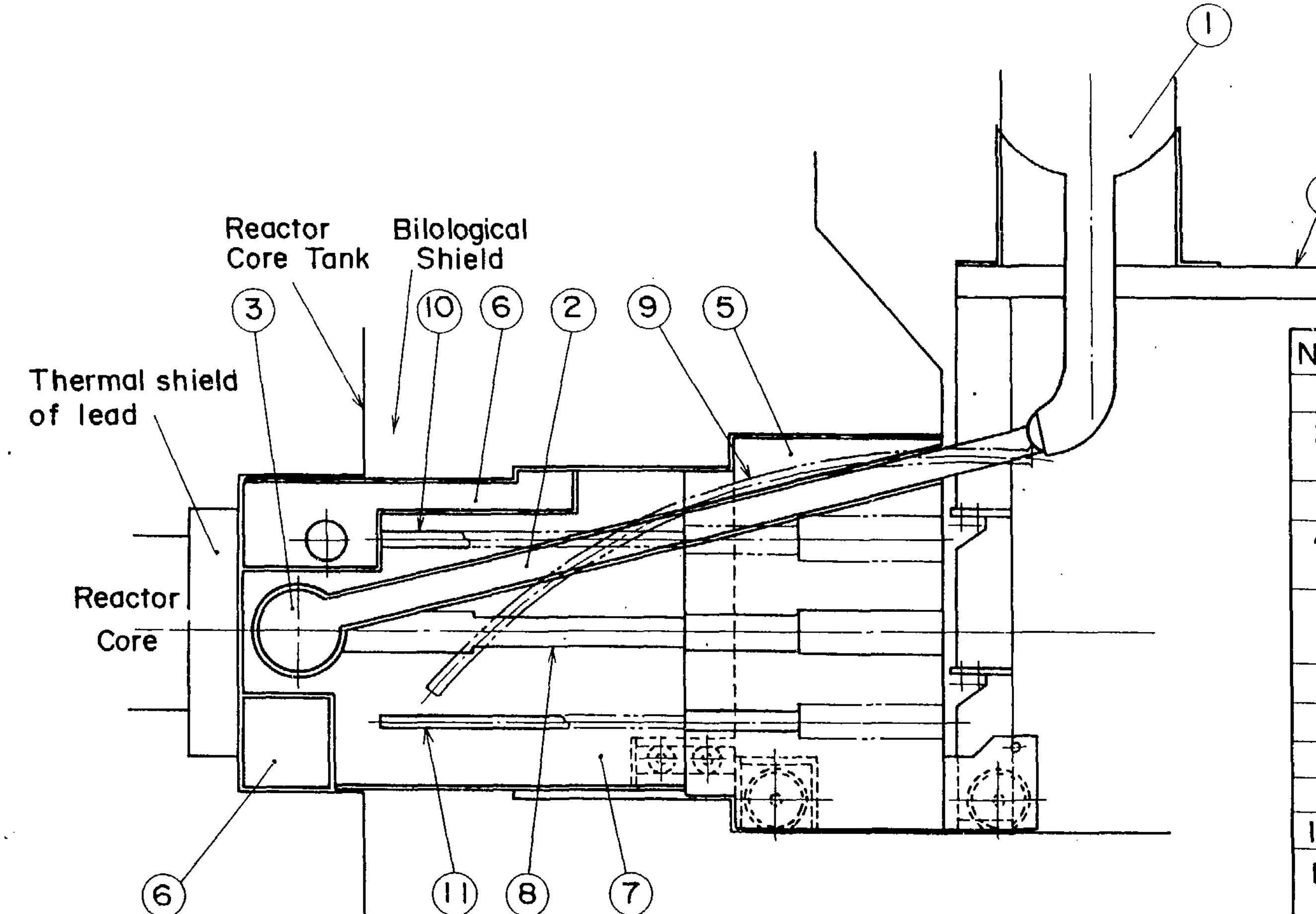
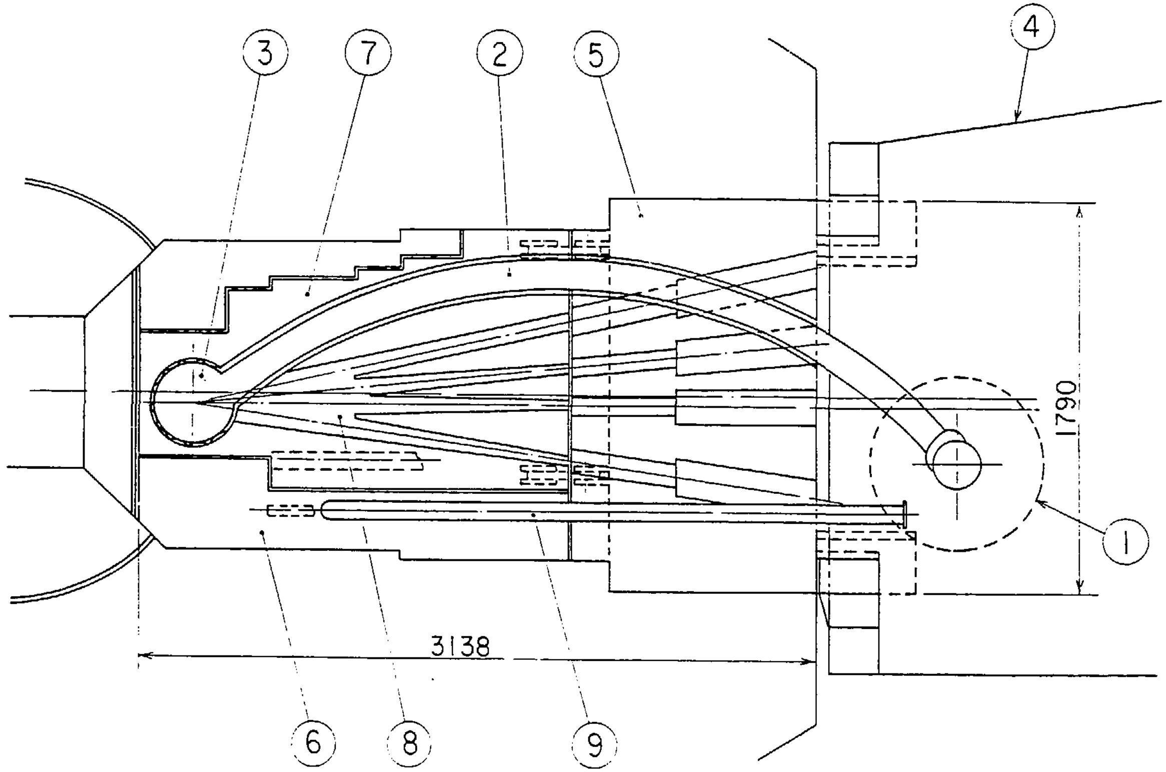
VERTICAL SECTION



No	Item
1	Condenser
2	Moderator transfer tube
3	Cold moderator cell
4	Earthquake-proof platform
5	Mobile shield of heavy-concrete
6	Fixed graphite
7	Movable graphite
8	Cold beam hole
9	Pneumatic tube
10	Thermal beam hole
11	Long-time irradiation hole

PLAN

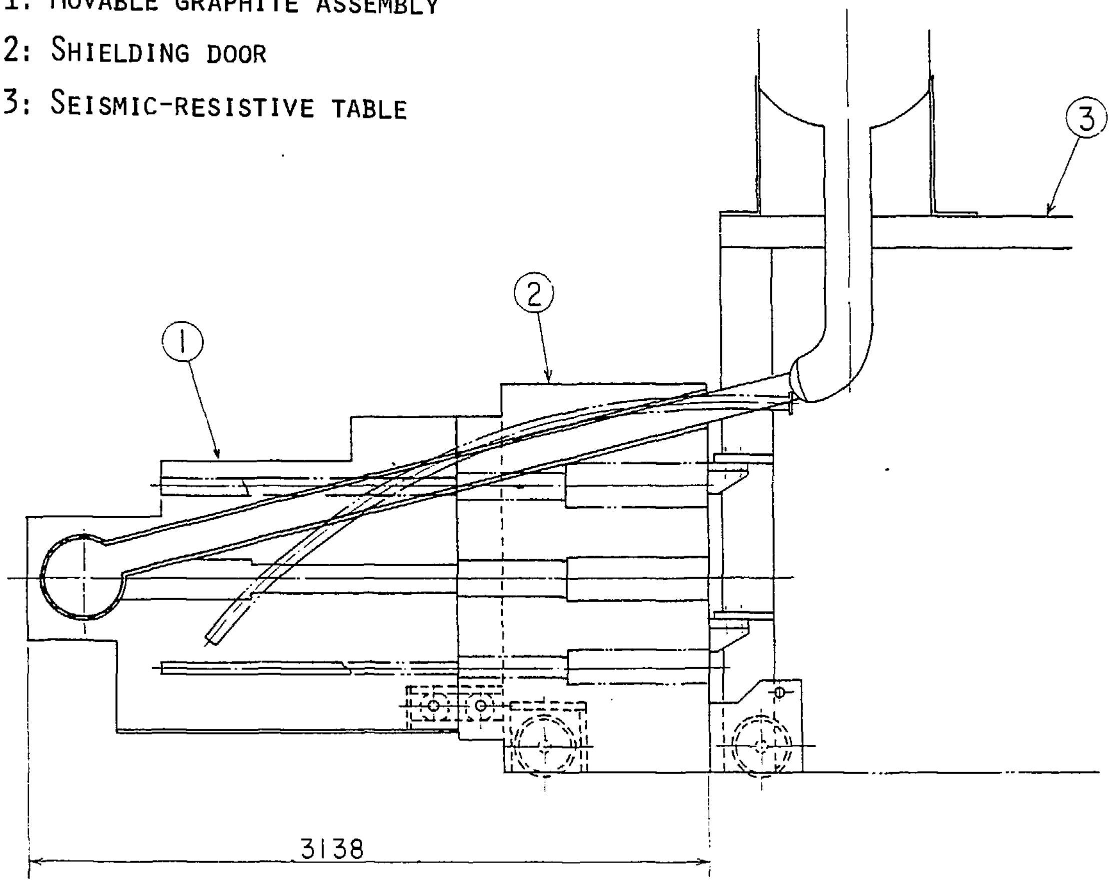


SM-310/11CP, Fig. 2 (b) (M. Uetsuki)

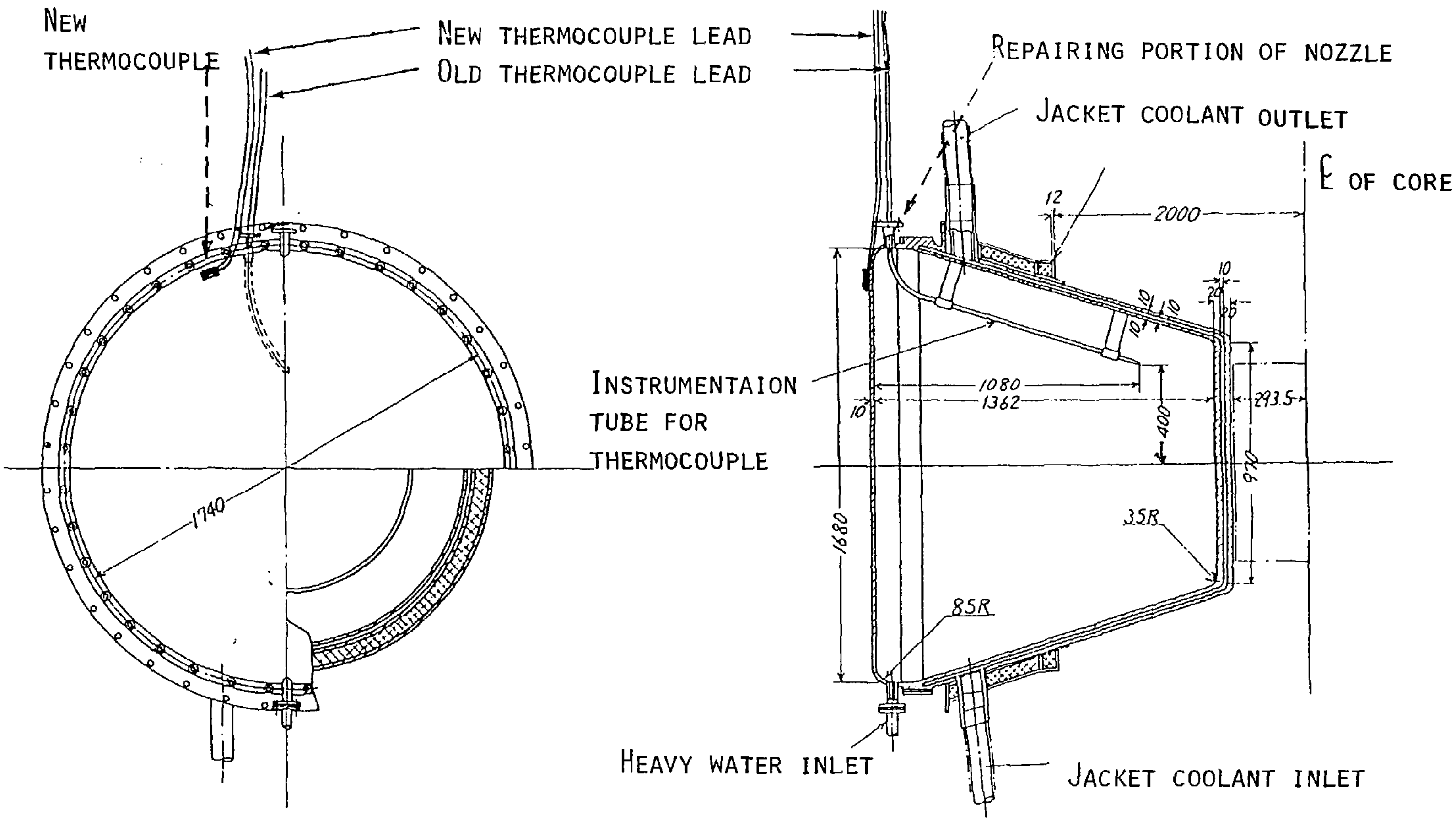
1: Movable graphite assembly

2: Shielding door

3: Seismic-resistive table



SM-310/110P, Fig. 3 (M. Utsuro)



NEW THERMOCOUPLE
NEW THERMOCOUPLE LEAD
OLD THERMOCOUPLE LEAD
REPAIRING PORTION OF NOZZLE
JACKET COOLANT OUTLET
℄ OF CORE
12
2000
10
20
20
10
10
10
10
INSTRUMENTAION TUBE FOR THERMOCOUPLE
1080
1362
10
293.5
400
920
1740
1680
35R
85R
HEAVY WATER INLET
JACKET COOLANT INLET

Fig. 1