One Piece Reactor Removal : An Innovative Approach for Research Reactor Renewal

by

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ABSTRACT

The strategy of Taiwan Research Reactor Renewal plan is to remove the old reactor block with One Piece Reactor Removal (OPRR) method for installing a new research reactor in original building.

Based on this strategy, a total weight of 2,800 T, Taiwan Research Reactor block including reactor core and biological shielding is being planned to be removed and transported from its in-site place to the underground storage vault which is located at the west outside of the reactor building for long-term underground storage.

The major subsystems to transport this reactor block include that the transportation work of reactor block lift-up, the work of reactor block horizontal transportation and the transportation work of reactor block lowering. The work of reactor block lift up is to transport the reactor block from its original pedestal wall position to the first floor slab. The work of reactor block horizontal transportation is to move the reactor block from first floor slab through a temporary opening on the west building wall to outside underground storage vault. The work of reactor block lowering is to lower the reactor block from the top to the bottom of storage vault for underground storage. In this paper, the engineering design of each transportation works including the work method, the major equipments, the design policy and design criteria is described and discussed. In addition, to ensure the reactor block is safely transported for storage and to guarantee the integrity of reactor base mat is maintained for new reactor, operation safety is drawn special attention, particularly under seismic condition, to warrant safe operation of OPRR. ALARA principle and Below Regulatory Concern (BRC) practice were also incorporated in the planning to minimize the collective dose and the total amount of radioactive wastes. All these activities are introduced in this paper.

Introduction

Taiwan Research Reactor (TRR), is a 40 MW natural uranium heavy-water moderated, light-water cooled research reactor similar in design to the NRX reactor at Chalk River in Canada. Construction of TRR started on September 1969 and the reactor reached its first criticality on January 1973 with the maximum thermal neutron flux of 6×10^{13} n/cm²-sec.

With the steady growth of the national nuclear power program as well as peaceful use of atomic energy over the past two decades, R&D and radiation service requirements imposed on TRR became more and more demanding. Various ideas of improving the capability of TRR, such as converting the TRR fuel into oxide fuel with low enrichment were recurrently attempted. However, due to safety and economic reasons, these attempts only came to limited success and the ability for TRR to support all R&D efforts were inevitably constrained. Therefore, in order to fulfill the ever increasing experimental need, a major renewal program aiming to improve the performance index of TRR by at least a factor of 10 was initiated and TRR was shutdown on January 1988.

With the shutdown of TRR on January 1988, various proposals aiming to upgrade the TRR were suggested. These proposals were evaluated against the screen criteria in terms of technological feasibility, safety, amount of radioactive wastes, radiation dose, flexibility of future experimental arrangement, and overall schedule and cost. Results indicated that the innovative approach "One Piece Reactor Removal" invented by Shimizu Corporation (SC) and Japan Atomic Energy Research Institute (JAERI) for JRR-3 renewal was most advantageous over other options and deemed to be the best choice for TRR renewal program. A joint team consisting of INER and SC engineers was subsequently formed to carry out the conceptual and actual design of TRR OPRR. Technology advancements since the completion of JRR-3 OPRR as well as the technologies pertinent to the TRR specific design are incorporated in the design. In this paper, the general arrangement of Taiwan Research Reactor block is described first for giving reader a general idea of TRR. Overall sequence and general description of TRR OPRR are described in second section for understanding the overallpicture of TRR OPRR work. The engineering design of the transportation works as well as the safety countermeasures for each subsystem in TRR OPRR are introduced in third section. Finally, the current status and future activities of TRR OPRR are summarized.

General Description of TRR Reactor Block

The general arrangement of the reactor is shown in Figure 1. The reactor proper is supported on an I-beam frame which in turn is supported on four heavy steel columns which extend to the main concrete support slab.

The steel floor plate, 5 in. thick by 18 ft. diameter, supports the lower thermal shields, the calandria, the graphite reflector and the cast iron side thermal shields. The floor plate rests on the I-beam frame.

The top axial thermal shields, the four removable biological shields and the outer ring of fixed biological shields at the top of the reactor are supported on the main concrete biological shield structure.

Additional shielding above the reactor is provided by the master plate located immediately above the top removable biological shield. The rods are supported on the shoulders of bevelled holes in the master plate. The plate is supported on stepped shoulders in the biological web, the cast iron pedestals which also support the four biological shields.

The upper cooling water header is supported by saddles on the master plate. The feed pipes are connected througe expansion joints so that the header is free to move radially.

The revolving floor at the top of the reactor is supported on a cylindrical steel shell to form the upper header room enclosure. The fuel rods extend from the upper header room through the reactor to the lower header room. Vertical pipe chases in the shielding concrete are provided between the upper and lower header rooms.

The graphite reflector extends to the face of the reactor on the east side of the structure forming the thermal column which is a source of thermal neutrons for experiments.

To reduce the radiation to biological tolerance, a wall of concrete eight to ten feet thick surrounds the reactor. It is separated from the side thermal shields by a 2 inch annular gap and is pierced by many experiment and instrument holes and by the thermal column. A large safety factor is used in specifying the thickness of the concrete so that a safe radiation level is assured in the working area around the reactor.

Engineering Design of Reactor Block Transportation

General Descriptin of TRR OPRR

Fig. 2 depicts the overall sequence and the bird's eyeview of the TRR OPRR total system. In advance of OPRR site work, experimental apparatus surrounding the reactor block have to be disassembled, all leak boundaries of the reactor block have to be sealed and checked, the working space for OPRR (within 5m of reactor block) has to be prepared, and work for radiological safety has to be established. Depending on the access to the reactor core and the contamination level during year's operation, a total of 101 leak boundaries are divided into 4 categories. Stainless steel,carbon steel or aluminum plate will be used to seal these openings and checked afterwards by PT method according to national codes and standards. After this site preparation work is done, the reactor block is first separated horizontally from the north and south pedestal wall and installed with sliding shoe, pathway, support beam, lift-up jack, and underpinning underneath the reactor block. It is then separated horizontally from the west and east pedestal wall and installed with lift-up jack and underpinning. Adequate and sufficient reinforcement is then installed to secure the integrity of structure and the reactor is now ready for vertical separation along the outer edge of the pedestal wall.

After separation of the four steel columns,the reactor block is lifted-up by hydraulic jacks with capacities of 150t and 20cm stroke. Shoring jacks (proof stress of their screws greater than 100t) are used as the underpinning jacks, and the underpinning piece is assembled with H-shaped steel.

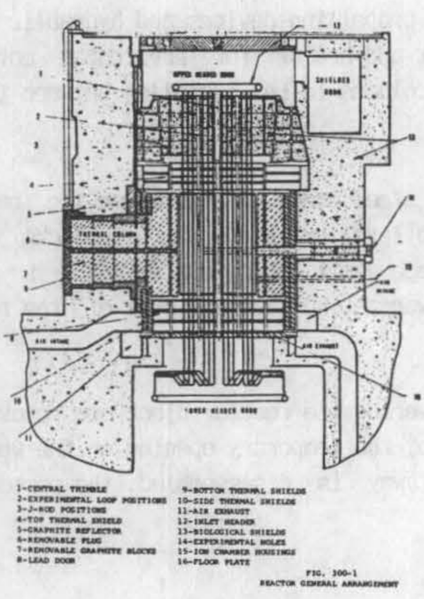

Fig. 1 The general arrangement of TRR

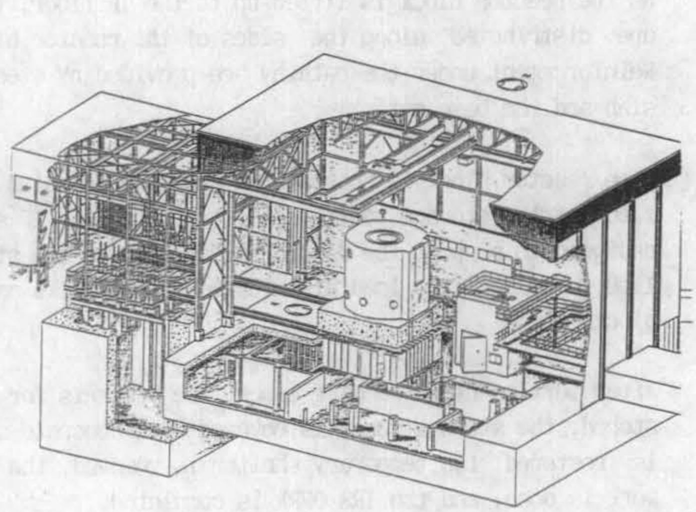

Fig. 2 The bird's eyeview of TRR OPRR

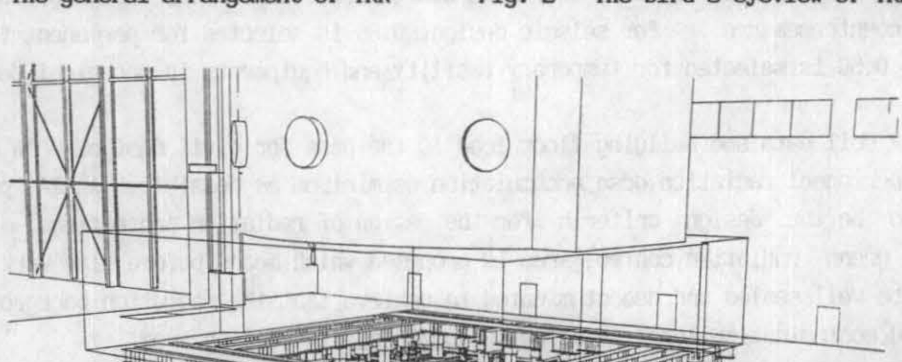

Fig. 3 The lift-up transportation

In parallel with the site preparation work for OPRR, an underground storage vault (17m X 15m X 18m) is excavated west of the reactor building. After a temporary shelter is built on top of the storage vault, the west wall of the reactor building is opened with temporary opening and a pathway is built to facilitate the transportation of the reactor block.

As the reactor block is lifted-up to the 1F floor, the propelling devices and hydraulic jacks are distributed along the sides of the reactor block and are set for horizontal movement. Reinforcement under the pathway are provided by steel columns to be installed between the 1F slab and the base mat.

When reactor block is approaching the storage valut, a steel stage, assembled on the basement floor of the storage vault, is lifted up to the 1F slab level by the center-hole jacks. It is designed to support the reactor block down to the storage vault. Load control unit is installed to balance the load distribution among jacks and warrant horizontal level of the reactor block.

After settlement of reactor block, the brackets for lowering the reactor block are removed and stored, the storage vault is covered with concrete slab, the temporary opening on the west wall is restored, the temporary shelter is removed, the pathway is disassembled, the restoration work is done, and the TRR OPRR is completed.

Design Criteria and Policy

Single failure criteria is selected to be the design criteria for the design of control system and safety countermeasure. For seismic design, 0.8G is selected for permanent facility and equipments. 0.5G is selected for temporary facility and equipments in mechnical design.

Original TRR soil data and building floor load is the base for civil design. In addition, to reduce the personnel radiation dose accumulation as minimum as possible, ALARA principle is selected to be the design criteria for the design of radiation protection. Under this principle, green radiation control area is proposed which means before site work the reactor block will be well sealed and decontaminated to achieve that the radiation background is below 2.5mR/hr and contamination level is below $100 dpm/100 cm^2$ in working area.

Reactor block leak sealing is performed according to the table 1.

Class	Description	Qunantily
Class Ⅰ	Activated and contaminated holes and openings	20
Class Ⅱ	Directly contact with contaminated holes and openings	55
Class Ⅲ	Indirectly contact with contaminated holes and openings	20
Class Ⅳ	Openings and holes with potential leak risk	6

Table 1. The positions of reactor block leak sealing

Prior to the actual design work, case study and preliminary design for the TRR OPRR were performed and the most situable method for TRR was recommended. Based on the conclusion, the design policy of OPRR's system is to satisfy the following four requirements :

- Minimum damage to the existing facility and building.
- Prevention of radioactive diffusion.
- Reduction of radioactive exposure.
- Reduction of radioactive waste volume.

Design of Reactor Block Lift-Up Transportation

Fig. 3. depicts the work of reactor block lift-up transportation.
After vertical and horizontal separation, the reactor block is separated from its pedestal wall and the first floor slab. With hydraulic jacks and underpinning material piece, step by step , the reactor block is transported from its original position to the first floor slab level position for horizontal transportation.

The major equipments and components used in lift-up transportation are listed in table 2.

Name	Purpose	Quntity	Specification
Underpinning piece	To shore reactor block weight	*	H-shaped steel beam
Hydraulic jack	To lift-up reactor block	40	150t or more
Journal jack	To support reactor block weight	48	100t or more
Control unit	To control lift-up work	1	Industry microprocessor

Table 2. The major equipments and components in reactor block lift-up

Safety countermeasures are designed against earthquake, equipment failure, power failure and fire. As an earthquake countermeasure during lift-up, the underpinning piece is provided with a horizontal joint for every six stories, and the underpinning pieces are fastened togeter to make them into one piece. In case of oil leakage in the hydraulic system or if the hydraulic piping puncture, a safety valve is provided on the hydraulic jack side to stop the oil flow automatically and prevent the cylinder from falling. In case the power supply stop, the system operation stops completely and the solenoids assume the locked condition for safety.

Design of Reactor Block Horizontal Transportation

Fig. 4. depicts the work of reactor block horizontal transportation.
Before the horizontal transportation, two stainless steel pathway with two active rails have been installed from reactor block position through first floor slab to the steel stage which is located at the top of storage vault, and underground storage vault has been constructed.

With two sliding shoes, which are composed of stainless steel with Teflon surface and are installed underneath the reactor block, and by two hydraulic jacks which are clamped in the active rails on two pathway used as propelling device, the reactor block is step by step pushed forward to the top of steel stage.

The major equipments and components used in horizontal transportation are listed in table 3.

Name	Purpose	Quntity	Specification
Sliding Shoe	To move reactor block	2	Stainess steel and Teflon furface
Hydraulic Jack & Clamp	To push the reactor block forward	2	100t or more
Pathway	To guide the reactor block	2	SUS304
Active rail	To active with hydraulic jack	2	SM50A

Table 3. The major equipments and components in reactor block horizontal transportation.

Safety countermeasures are designed against earthquake, equipment defects, power failure, and fire. As an earthquake countermeasure during horizontal movement, One of the rail clamps set in front and in rear of the propelling jack is always grasping the rails allowing for effective resistance of the horizontal force during on earthquake.

In case of oil leakage in the hydraulic system or if the hydraulic piping breaks, the safety valve mounted on the hydraulic jack side automatically stops the oil flow immediately preventing the cylinder from falling. The power source for the hydraulic unit is a dedicated circuit, however, if the power stops, the system operation stops compeletly, and the solenoids lock for safety.

Design of the Transportation Work of Reactor Block Lowering

Fig. 5. depicts the transportation work of reactor block lowering.

A steel stage, which is composed of H-shaped steel beam and located at top of storage vault, is connected with 24 center-hole jacks which in turn are supported by brackets which are supported and located at the south and north side of storage vault. After reactor block is transported on the steel stage, by these center-hole jacks, the steel stage together with reactor block is lowered step by step down to the bottom of storage vault.

The major components and equipments used in the work of reactor block lowering are listed in table 4.

Name	Purpose	Quntity	Specification
Steel-stage	To stage reactor block	1	H-shaped stainless steel beam
Conter-hole-jack & braked	To lower reactor block	24	200 t
Control unit	To control center-hole jack and perform lower control	4	Industry microprocessor
Load balancer	Balance the unbalance load	1	*

Table 4. The major equipments and components in reactor block lowering

Safety countermeasures are designed against earthquake, power failure, piping damage and fire. As a protective measure for earthquake during lowering operation, rubber ect. is installed to the steel stage to protect against horizontal shaking. Thrust bearing is installed in each center-hole jack to prevent from excessive bending caused by horizontal force. A mechanism is provided by which, when reactor block is being lowered, if breakage occurs in piping, the hydraulic pressure will not be lost, and the load will remain as it is. In addition, A device is installed by which the hydraulic mechanism will maintain the balance between the jacks and the load if pipe breakage occurs.

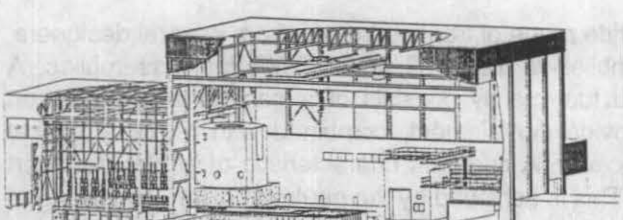

Fig.4 The horizontal transportation

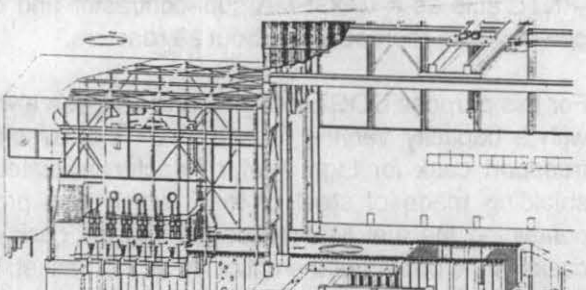

Fig.5 The lowering transportation

Conclusion

The Safety Anaysis Report of TRR OPRR has passed INER internal review organized by safety committee and soon will be submitted to AEC for another independent review. Local engineering companies are invited to participate in the detail design of the OPRR system. With the grant of construction permit, qualified contractor will be selected to carry out the actual site work of TRR OPRR. It is expected that excavation of the underground storage vault will be started in early 1993 and TRR OPRR will be completed by the end of 1994. Starting from then on, it is the new phase for TRR-II construction work