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# RESULTS OF ASSEMBLY TEST OF HTTR REACTOR INTERNALS

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**Abstract**

The assembly test of the HTTR actual reactor internals had been carried out at the works , prior to their installation in the actual reactor pressure vessel(RPV) at the construction site. The assembly test consists of several items such as examining fabricating precision of each component and alignment of piled-up structures, measuring circumferential coolant velocity profile in the passage between the simulated RPV and the reactor internals as well as under the support plates, measuring by-pass flow rate through gaps between the reactor internals, and measuring the binding force of the core restraint mechanism. Results of the test showed good performance of the HTTR reactor internals. Installation of the reactor internals in the actual RPV was started at the construction site of HTTR in April,1995. In the installation process, main items of the assembly test at the works were repeated to investigate the reproducibility of installation.

## 1. INTRODUCTION

The High Temperature Engineering Test Reactor(HTTR) being constructed by Japan Atomic Energy Research Institute(JAERI) is a helium gas-cooled and graphite moderated thermal reactor with 950℃ in reactor outlet coolant temperature and 30 MW in thermal output[1].

To achieve the high reactor outlet coolant temperature of 950℃, it is important to keep the maximum fuel temperature as low as possible. Therefore, from the core thermal/hydraulic(T/H) point of view, the coolant flow ineffective to direct core cooling, such as core by-pass flow, should be minimized. The reactor internals of HTTR are so designed as to restrict by-pass flow by sealing at surrounding graphite blocks of outer part of the core with tightly binding mechanism composed by metallic structures, and also as to cool for maintaining temperature of such metallic structures within their limit. The R&D works have been carried out to quantitatively asses the performance of these functions using partially simulated model and/or scale down mock-up[2].

The assembly test of actual reactor internals at the works was conducted to demonstrate that these design required functions were actualy achieved.

## 2.OUTLINE OF REACTOR INTERNAL

The core of HTTR is an array of hexagonal graphite blocks which provides the physical structure for the arrangement and confinement of fissile materials, neutron moderation, heat transfer and positioning of control/shielding absorber materials. The core is supported by the reactor internals such as permanent reflector blocks(PRBs), hot plenum blocks(HPBs), support posts, support plates, core restraint mechanisms (CRMs),etc. as shown in Fig.1 and Fig.2.

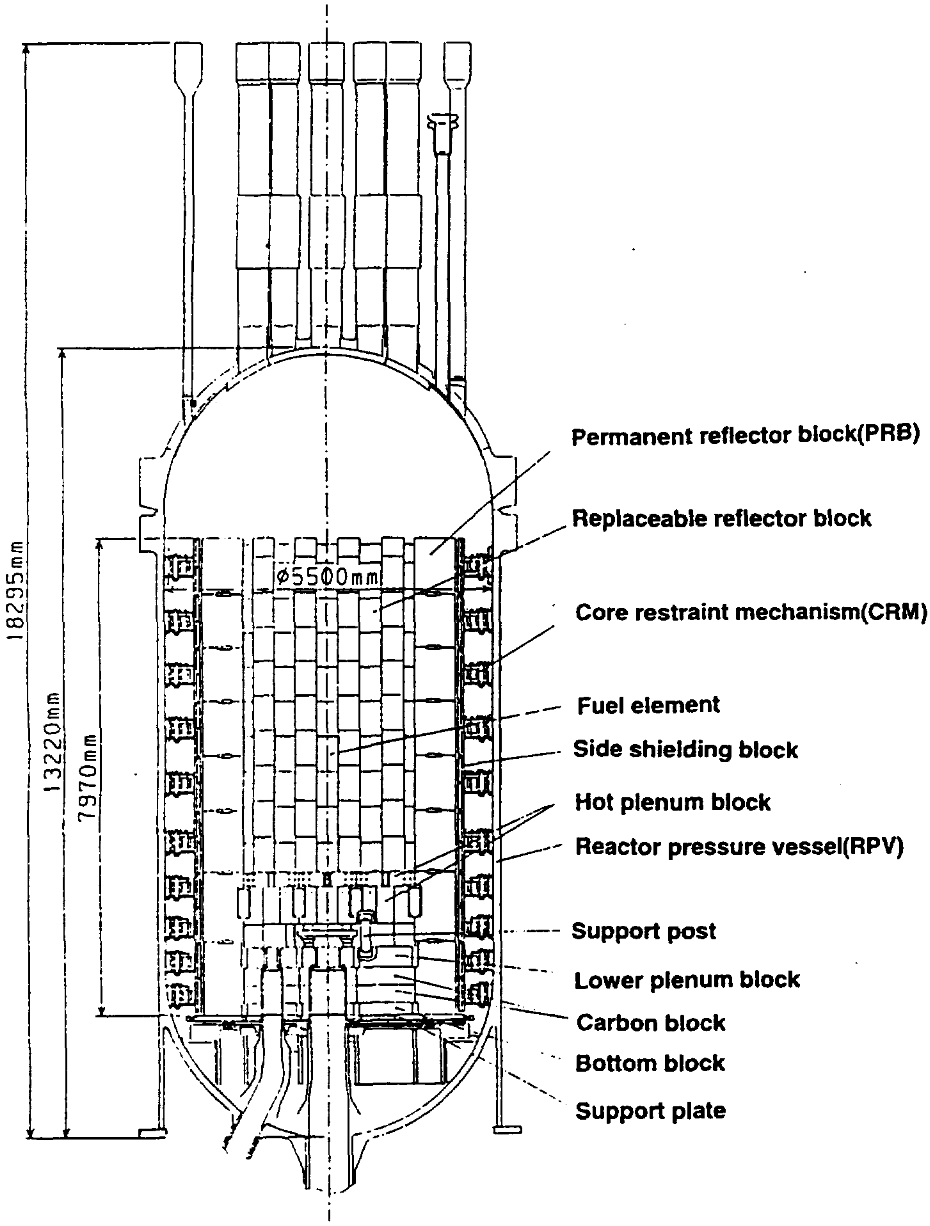


**Fig. 1 Cross section of HTTR**

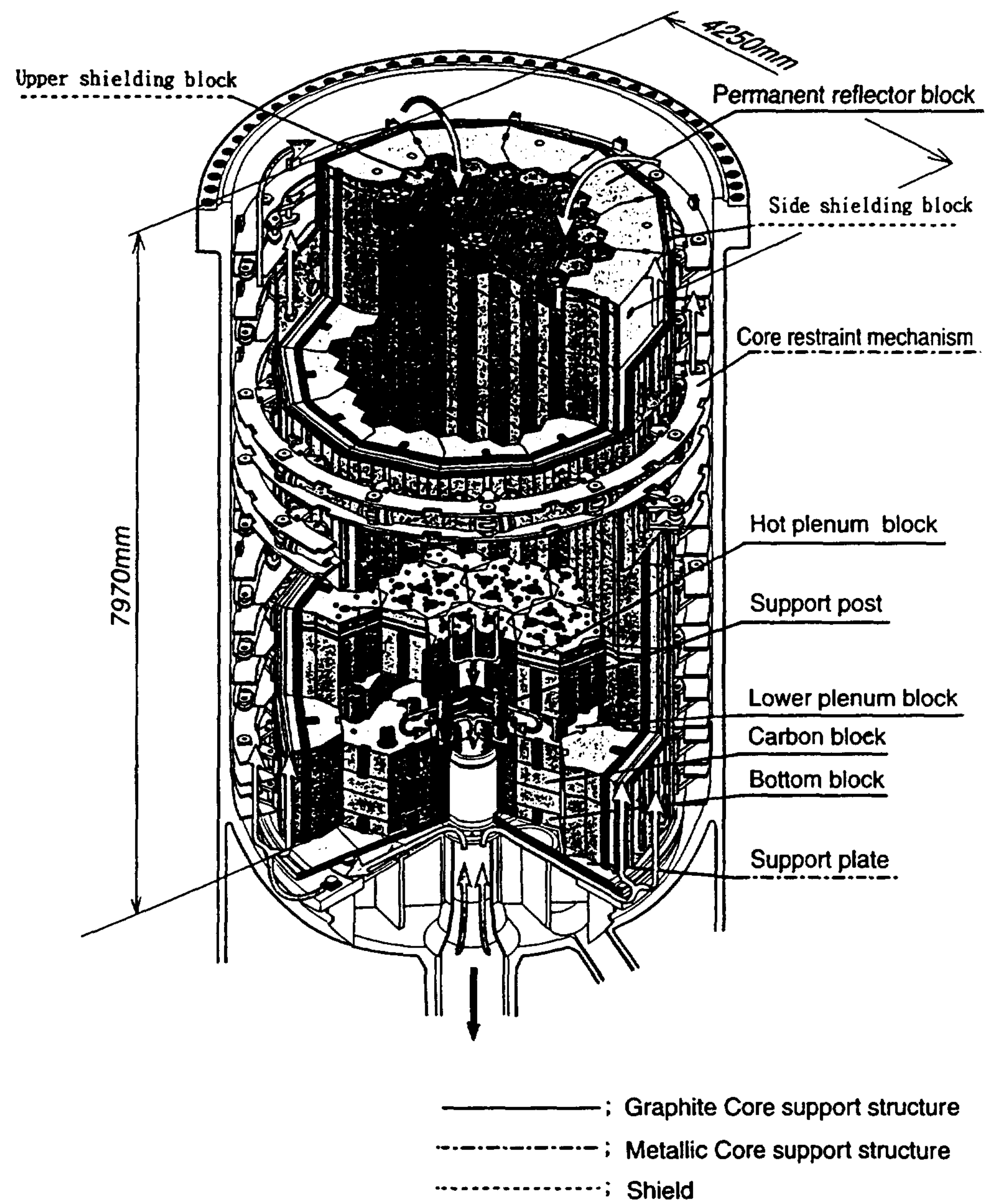


**Fig. 2 Bird's-eye view of the Reactor Internal Structure**

The reactor internals consist of the graphite core support structures, the metallic core support structures and the shielding blocks. The graphite core support structures mainly consist of PRBs, HPBs, support posts, and the core bottom insulation structures. PRBs consist of 8 axial layers of total hight about 8m. In each layer, PRBs surround the core element blocks and consist of 12 circumferential segments with the keys on the adjacent surface as shown in Fig.3. PRBs in each layer are binded each other by CRMs, and by-pass flow between adjacent blocks is restricted by face contact and seal elements. HPBs, support posts and the core bottom insulation structures are illustrated in Fig.4. HPBs are composed of the sealed blocks and keyed blocks. These blocks are located underneath the core elements to support them directly and to form passages of coolant flow from the core to the hot plenum. The gaps between the sealed blocks are sealed by

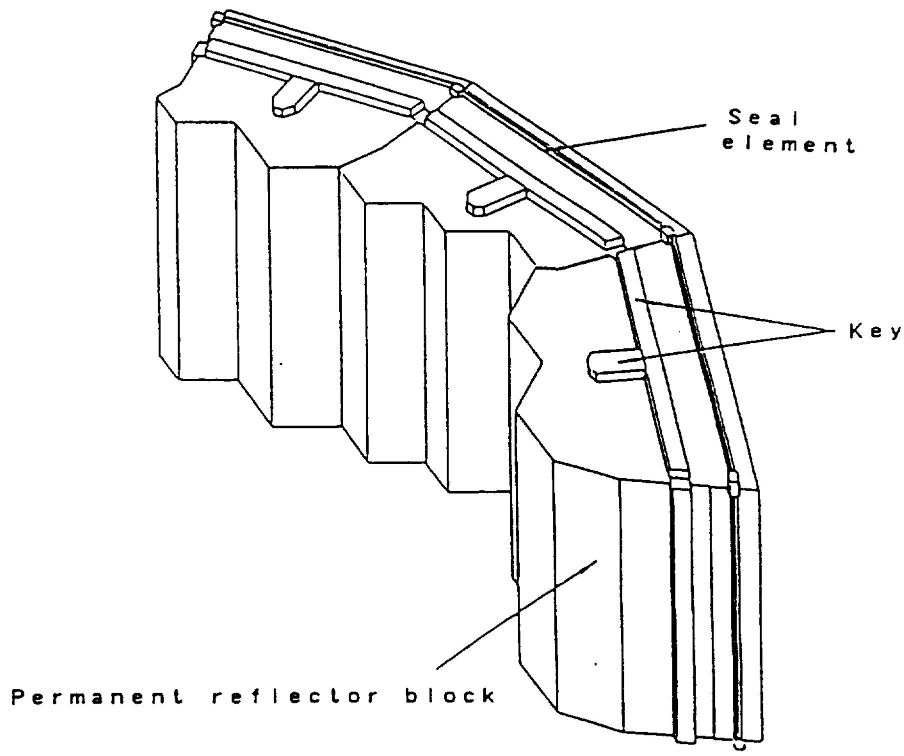


**Fig. 3 Schematic Diagram of the Permanent Reflector Blocks**

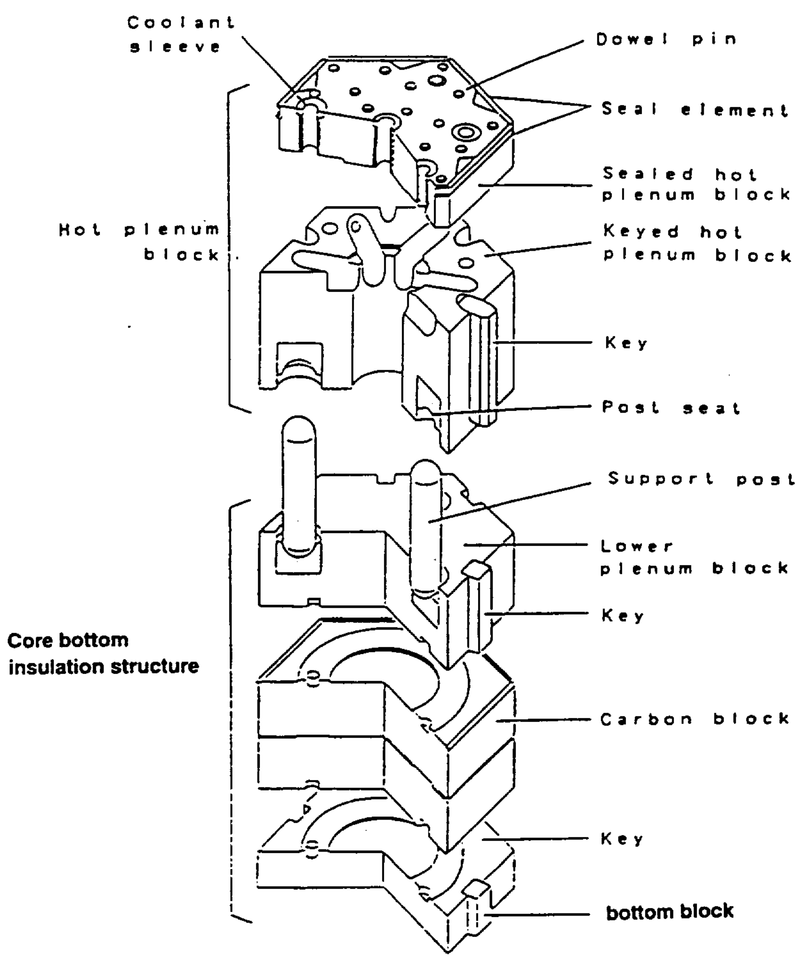


**Fig. 4 Schematic diagram of the Core Bottom Graphite Structure**

triangular seal elements to reduce gap flow between core element blocks which is not effective for core cooling. The support posts are located below the keyed hot plenum blocks and form the hot plenum. The core bottom insulation structures are located beneath the hot plenum and are composed of the lower plenum blocks,the carbon blocks, and the bottom blocks. These structures have the function to prevent temperature rise of the lower metallic core support structures.

The metallic core support structures support above-mentioned graphite structures and transmit the vertical and horizontal loads to the RPV. The metallic core support structures consist of the support plates and CRMs. The support plates forms a plain foundation surface for the core components and the reactor internals. The support plates are set on steel support posts and are cooled by helium gas which flows radially outward between two parallel plates; upper plate is the support plates and lower plate cover plate of the core support grid. CRMs are located between RPV and the side shielding blocks as shown in Fig.5. CRMs surround and bind PRBs like hoops for a barrel with 10 axially

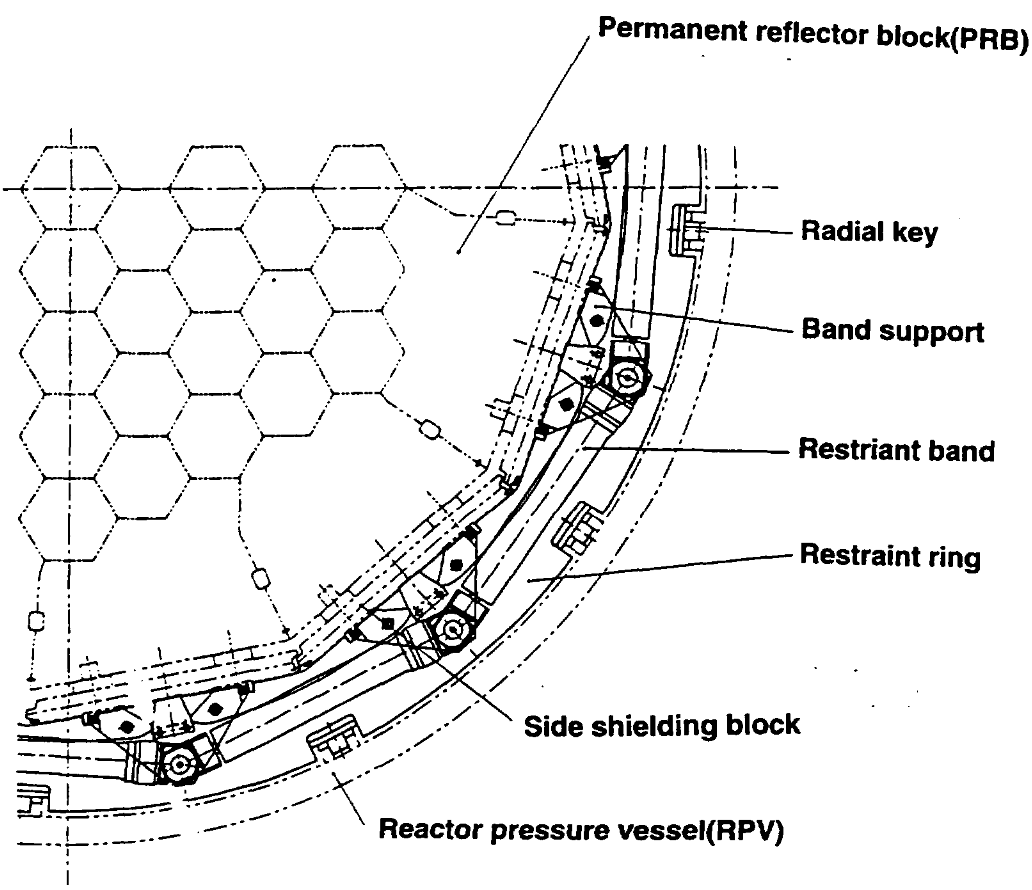


**Fig. 5 Schematic diagram of the Core Restraint Mechanism**

distributed units to restrict excessive by-pass flow through gaps between blocks by preventing radially outward movement of PRBs. CRMs are cooled by helium gas not to reduce binding force caused by relaxation of the tensile element material under high temperature creep condition.

The shielding blocks consist of the upper shielding blocks and the side shielding blocks. The upper shielding blocks are placed on the top of columns of the core and form the entrance to control flow rate distribution into the core. The side shielding blocks form the coolant flow path to cool the metallic structures in the core side.

The coolant enters in RPV through the annular passage of concentric hot gas duct, then, flows upward to the upper plenum via two side flow passages: one is an inner passage between the PRBs and side shielding blocks and the other an outer passage between side shielding blocks and the RPV. Finally, the coolant entering into the upper plenum flows downward to the hot plenum through the core via coolant channels in the fuel blocks and control rod guide blocks. Besides the bulk of the coolant flows through the core, small amount of the coolant flows through the gaps between adjacent graphite blocks. As the low temperature leakage flow is mixed with the bulk of the coolant in the hot plenum, the leakage flow brings the lower reactor outlet coolant temperature.

## 3. PROCEDURE OF ASSEMBLY TEST

In the assembly test at the works, the support plates, which form a foundation of stack, are placed in the simulated RPV, then, the graphite core support structures of PRBs, HPBs, support posts and others are piled-up onto the plates. PRBs are binded in tight contact by the CRMs. The cross sectional view of the test apparatus is shown in Fig.6.

Following items of the assembly test were conducted at the works.

(1) fabrication precision of alignment of piled-up structures

(2) seal performance against by-pass flow

(3) cooling performance for metallic structures

(4) binding performance of CRMs

The test procedure of each test item is described below.

(1) fabrication precision of alignment of piled-up structures

Each component is fabricated precisely, but the assembling precision of each component, alignment of piled-up structures and the level difference and gap width between blocks are of importance to confirm their effects on the T/H performance of the core.

Level differences and gaps between blocks, which affect by-pass flow or core cooling performance, were measured each time one layer was assembled, and also checked for unexpected leakage flow passage.

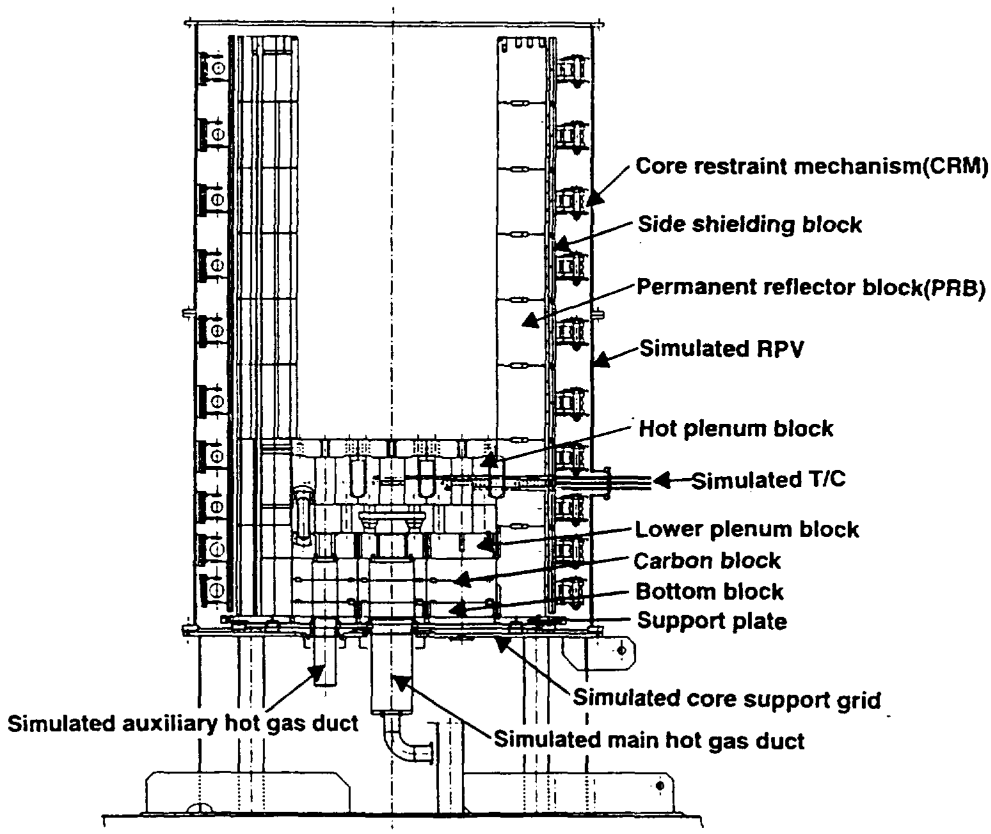


**Fig.6 Cross Sectional View of Test Apparatus**
**– The Assembly Test at the works**

(2) seal performance against by-pass flow

As shown in Fig.7, a sealing cap is set on top surface of PRBs to shut the open window, and pull air from cavity through the simulated concentric hot gas duct. In this configulation, leakage flow rate into the cavity through gaps of PRBs, the support plates and others were measured.

(3) cooling performance for metallic structures

The support plates and CRMs are cooled by helium gas of 400℃, so velocity profiles in the passage under the support plates and in the core side flow passage were measured by means of hot wire anemometers for evaluation of cooling performance.

(4) binding performance of CRMs

Binding force of the CRM was loaded by means of specialy developed hydraulic jack. The restraining force on each PRB was measured by load cells.

After completion of the assembly test at the works, installation of the reactor internals in actual RPV was started at the construction site of HTTR in April,1995. In the installation process, test items of (1),(2),and(4) were conducted to investigate the reproducibility of assembling.

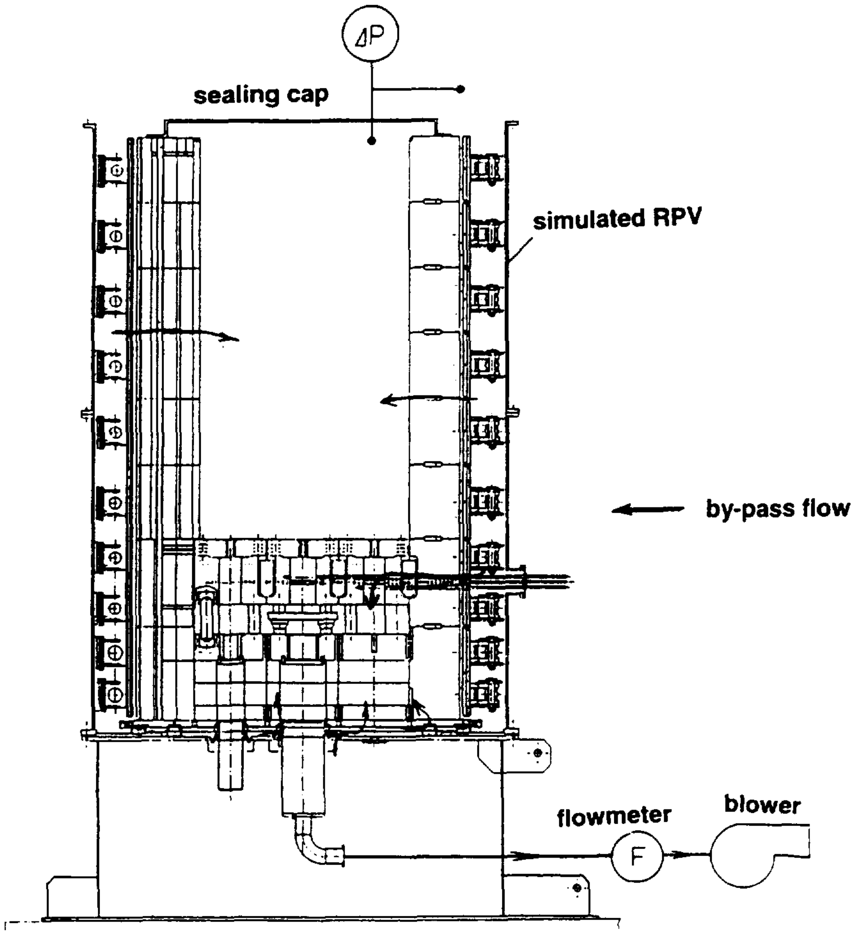


**Fig.7 Schematic Diagram of Seal Performance Test**

## 4. RESULTS AND DISCUSSION

(1) fabrication precision of alignment of piled-up structures

All measured data are in the range of design limit. For example, measured level difference between top surfaces of sealed block of HPBs are 0.7mm at maximum and this difference is sufficiently small compared with allowable limit of 4mm for triangular seal elements[3].

(2) seal performance against by-pass flow

The result of this test is shown in Fig.8. The solid line shows the upper limit of the leakage flow rate[4]. Because this test was carried out under the atmospheric air, not pressurized helium condition, the upper limit was converted from helium to air. While the upper limit of leakage flow rate is assumed to be 1% of total coolant flow rate in HTTR core T/H design, measured leakage flow rate is equivalent to 0.5% or less. Thus, the actual fuel temperature is estimated to be lower than the fuel temperature assumed in design by approximately 5℃.

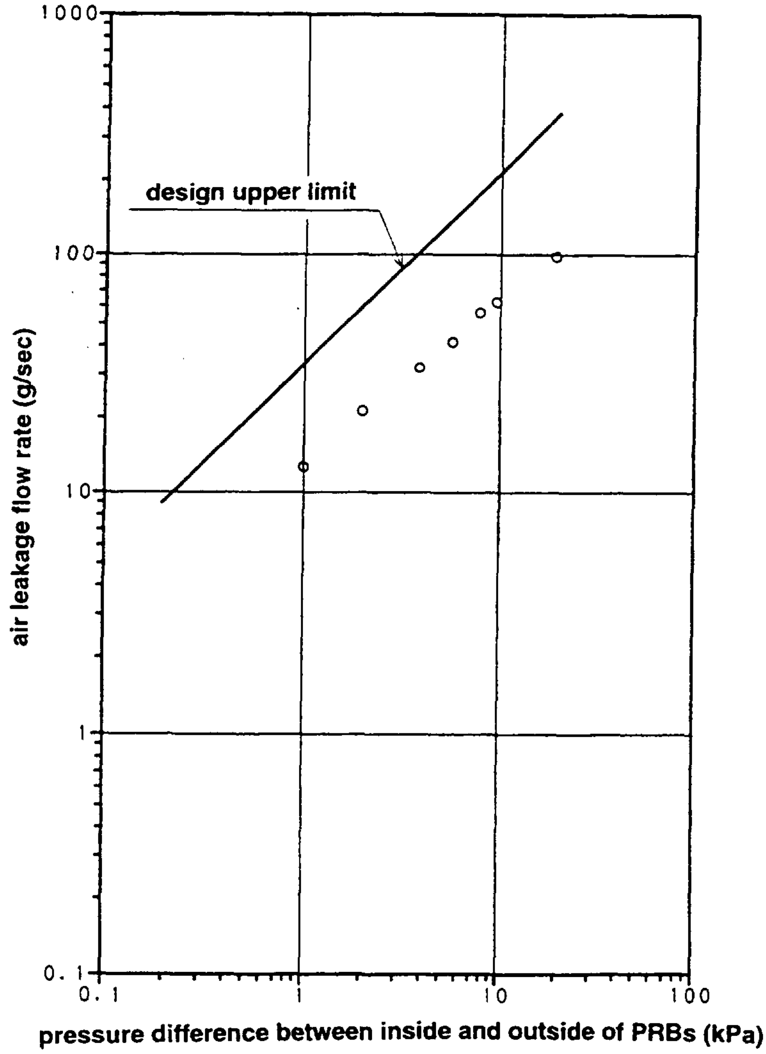


**Fig.8 Result of Seal Performance Test**

While conducting seal test,we also found unexpected by-pass flow path of key/keyway clearance of PRBs in the 7th layer, so the shape of these keys have been improved to eliminate the path.

(3) cooling performance for metallic structures

Measured air velocity profile at outer edge of the support plates is shown in Fig.9. Although there are some local fluctuations of velocity, it can be said that the flow under the support plates is almost uniform from the view point of their temperature distribution, in other words, structural integrity. Figure10 shows the measured flow distribution in the core side passage. Certain flow ratio in the inner passage is required to cool CRMs, because they are heated by radiation and conduction from the side shielding block. In the T/H design, we have conducted the 3-dimensional numerical analysis of whole core to evaluate reactor internal temperature. As a result, it was clarified that the flow ratio of 35% in the inner passage is necessary to maintain CRM temperature under 450℃,which was determined from the view of relaxation rate

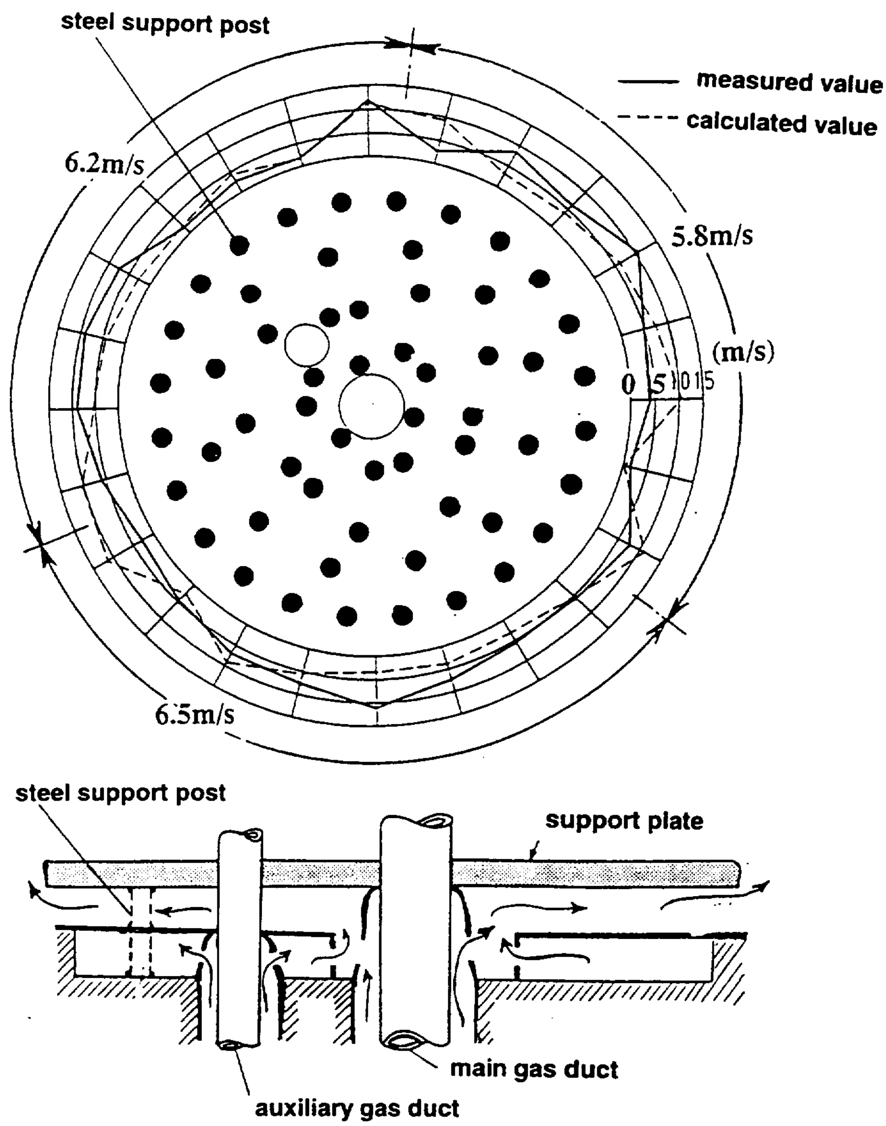


**Fig.9 Result of Cooling Performance Test
-- Velocity Profile under Support Plates**

of the restraint band. Therefore,the restraint rings were designed so as to restrict flow ratio in the outer passage by narrowing the gaps between the restraint ring and RPV. The flow distribution in the core side were finaly evaluated by the flow network analysis code FLOWNET[5]. Every open circle in the figure shows the flow ratio in the inner passage, which was measured after the reactor internals below the measuring position were assembled. The measured flow ratio satisfies the design limit at any level and agrees well with etimated value.

(4) binding performance of CRMs

Figure11 shows measured distribution of restraining force on PRBs by CRMs at bottom layer. Restraining force is loaded uniformly and fulfills its design value.

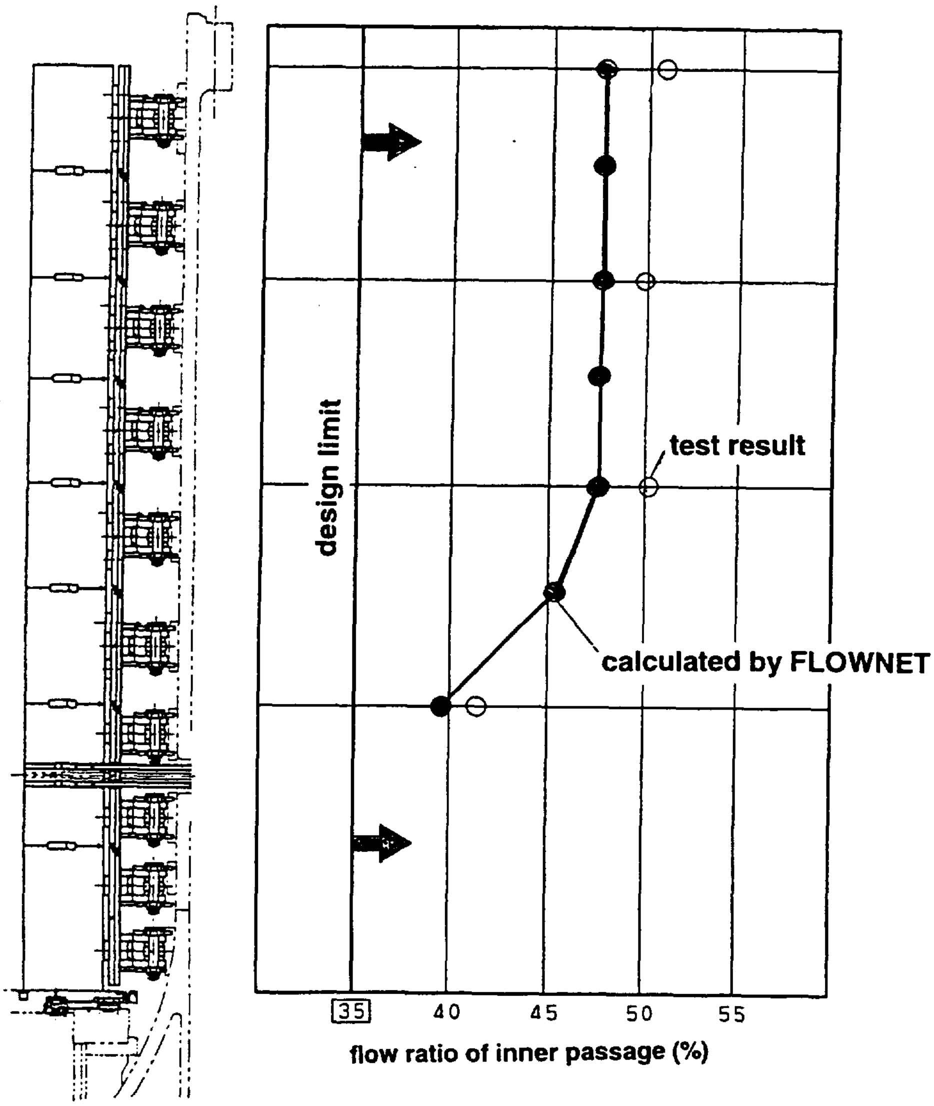


Fig.10 Result of Cooling Performance Test
–Flow Ratio of Inner Passage in the Core Side Passage

## 5. CONCLUSION

The assembly test of the reactor internals had been conducted at the works. As the result of the test, expected performances of sealing,cooling and binding function nessesary to achieve high temperature reactor outlet coolant of 950℃ were demonstrated. After completion of the assembly test at the works, the reactor internals have been installed in actual RPV from April to September,1995. Among these test items of the assembly test at the works, tests of fabrication precision, seal performance, and binding performance were repeated in installation process. Test results, both at the works and at the construction site, were equivalent and reproducibility at the construction site was confirmed.

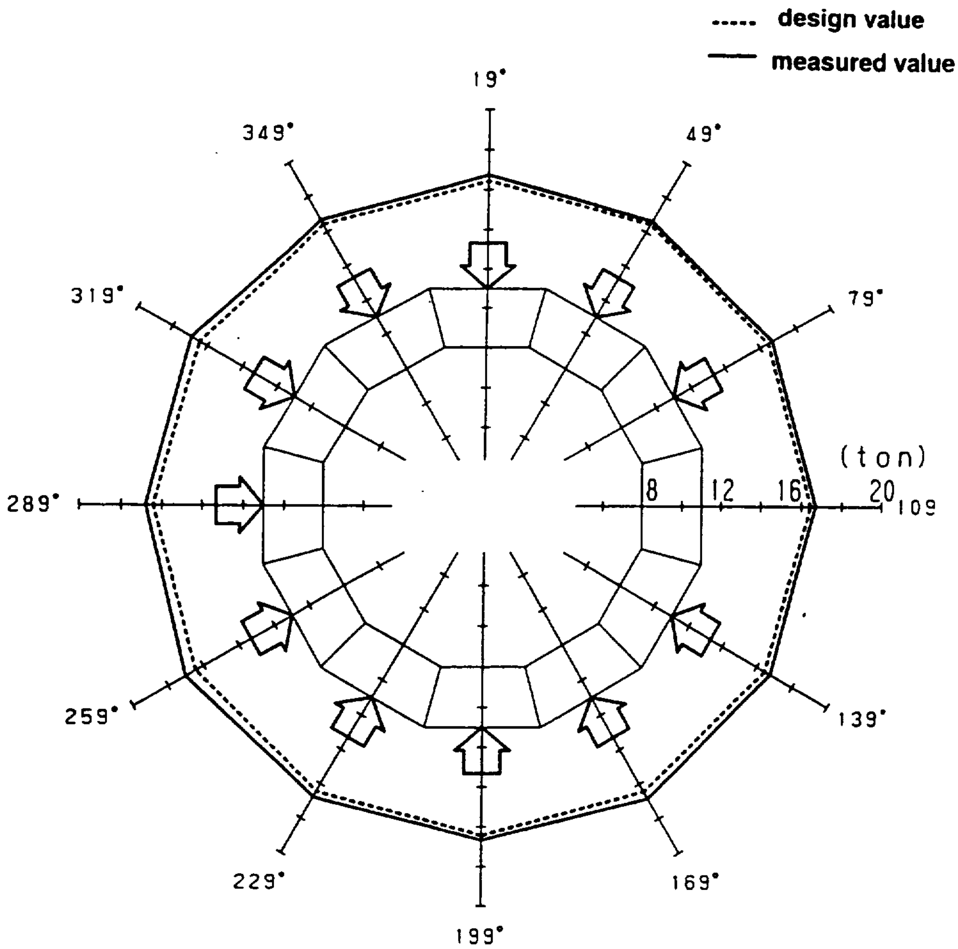


**Fig.11 Result of Binding Performance Test**
**-- Restraining Force on PRBs of lowest layer**

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