Installation of Research Reactor Assembly

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1. Introduction

The reactor assembly of JRTR (Jordan Research and Training Reactor) has been successfully installed at the site and its operability has been completely verified through several commissioning stages. Finally, it was turned over and started to operate from early 2017 by its owner. In this paper, strategy for successful implementation of the reactor assembly is explained and actual installation works of the reactor assembly are described with lessons learnt. The scope in this paper includes the reactor structure assembly, BPA (beam port assembly) and TCA (thermal column assembly) of JRTR. The general arrangement of reactor assembly is depicted in Figure 1.

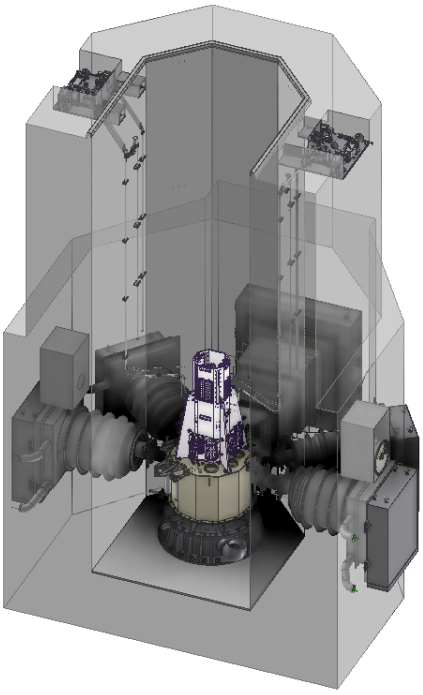

Figure 1 General Arrangement of Reactor Assembly

2. Strategy

2.1 Inherent Accuracy of Design

The design of the reactor assembly has intended matching or adjusting devices for precise alignment between neighboring components. Using these devices, most components can be easily installed and precisely aligned at the designated exact places from a reference coordinate system.

2.2 As-built

The construction of the reactor pool had not been completed dimensionally same with the drawings. Therefore, the as-built dimensions of reactor components and as-installed dimensions of the reactor pool were adopted in advance during fabrication of the adjusting parts of the reactor assembly.

2.3 Pre-Assembly

Although installation sequence is well established in the design stage and verified with fabricated components, there can be various unexpected difficulties in actual installation works. It is very helpful to practice the installation sequence and to assemble components beforehand. So, the pre-assembly of the reactor assembly had been planned and performed identically with actual installation sequence at the factory before shipping.

2.4 Outstanding Equipment

Laser tracker system [1] is basically applied both in fabrication and installation stage, which is known as one of the most precise and efficient measuring equipment in diverse industries. The equipment is irreplaceable when measuring three dimensional shape of the components in fabrication process and their spatial positions in installation site.

2.5 Well Trained Personnel

Because the components of a research reactor assembly are very distinctive and sensitive structures, they shall be handled carefully according to instruction manual by skilled workers. So, it is strongly demanded that well trained experts shall be accompanied from the pre-assembly to the installation stage. Even for helpers at the installation site, they are necessary to be trained from the leading experts.

3. Installation Works and Results

In this section, actual installation works and results compared to the criteria are described in detail. Practically, works for several components were proceeded simultaneously and sometimes repeated, if necessary.

3.1 Creation of Coordinate System

The origin and coordinate system of the reactor assembly were constructed reflecting the as-built dimensions of the reactor pool. They should be applied for aligning and positioning of the components or structures related to the reactor structure assembly. The virtual flat planes from real bumpy wall and gravitational direction were used to build the coordinate system. Considering configurations of BPA and TCA to be achieved together with the reactor structure assembly, the optimal origin and Cartesian coordinate were determined. It was also verified that other components like control rod drive mechanism, second shutdown drive mechanism, refueling cover, etc. could be installed in place within required tolerances. Both the permanent and temporary SMR (Spherically Mounted Retroreflector) nests were installed in the reactor pool, on the reactor pool top, reactor concrete wall and reactor hall floor for complete retrieval of the coordinate system when necessary.

3.2 Reactor Structure Assembly

The outlet plenum, grid plate, heavy water vessel and upper guide structure were installed sequentially. Since the outlet plenum was the base component for all components of the reactor assembly, it is most important to set the outlet plenum as precisely as possible. The requirements of the outlet plenum alignment were as follow. The alignment should be less than the slope of 0.1 mm/500mm on the top of the grid plate and 1mm/2m on the top plate of the grid plate. The position should be within ±0.5mm and orientation within ±0.5°. The results were slope of 0.032mm/500mm on the top, slope of 0.087mm/2m on the top plate, position within ±0.5mm, orientation within ±0.01°.

After complete installing of the outlet plenum and grid plate, slope of 0.08mm/471mm was confirmed on the top of the grid plate. It was also confirmed that all nest holes were horizontally within the criteria.

The heavy water vessel was easily positioned using four alignment pins on the grid plate and assembled by tightening bolts with the grid plate. The slope on the upper plate of completed heavy water vessel was 0.103/685.65mm within the criteria of 1mm/2m.

The upper guide structure was properly installed according to the approved procedure. Elevation of the top of the upper guide structure was measured and it was 4508.4mm (design: 4510.0mm) from the origin. The gap between the upper guide structure and the refueling cover was achievable within the criteria (2.0mm) by adjustment of the reactor pool working platform.

3.3 Beam Port Assemblies

Since the beam tubes of heavy water vessel had been welded within acceptable alignment tolerances, Four BPAs should be aligned reflecting the as-built dimensions of them. The horizontal angle and height of the beam tubes should be considered in installation of BPA housings. Also, the distances between the heavy water vessel and BPA housings should be restricted for the expansion joint assembly.

Using the laser tracker system both in the reactor pool and reactor hall, all four BPA housings were aligned very well. The criteria were met, which enforced two end centers of each beam port housing to be within ±1.0mm along the straight line from each beam tube. The differences in all BPAs were mostly within 0.5mm except one of 0.83mm. The embedded 8 adjusting screws were very useful to move the BPA slightly, but precisely to the right position iteratively.

After constructing connected structures such as casings and filling concretes, internal parts for shielding and guiding neutrons were inserted using a specially invented cart. It was confirmed that windows for neutron channels were in place along the straight line from each beam tube. The expansion joint assembly was just placed and tightened between the heavy water vessel and the BPA housing, since the distance was already fit to the length of the expansion joint assembly.

Finally, the operability of the standard BPAs and required leak-tightness for all the site-weld area and mechanical joints were verified in accordance with the approved procedure.

3.4 Thermal Column Assembly

As mentioned, the origin and coordinate system were determined considering installed configuration of pool liner for TCA and BPA. One of main parameters considered was the gaps between TCE (Thermal Column Extension) and the heavy water vessel, the gaps between TCE and the pool liner for TCE. Therefore, TCE should be installed near the right middle between the thermal column liner and heavy water vessel. The support structure which determines the position of TCE was carefully aligned and installed. The requirements for the installed support structure are perpendicular direction within ±1.0mm, parallel direction within ±5.0mm, and slope within ±0.5mm/500mm on the top surface. The results were perpendicular direction within ±0.3mm, parallel direction within ±3.5mm, and slope within ±0.2mm/500mm. On the support structure, TCE was simply installed as planned.

The internals for irradiation such as graphite blocks, boral plates and lead bricks for gamma shielding inside the thermal column housing were inserted as designed. Finally, the handling of target stringer assembly was properly tested for removal and insertion commissioning in the irradiation space.

4. Conclusion

The installation of the research reactor assembly had been successfully completed despite of its intrinsic difficulties. It was clear that the strategy was well established in advance and perfectly applied in actual installation processes. All the components have been installed properly as planned in accordance with the approved procedures and the results have met the strict criteria. In the commissioning stages, the quality of the installation and the system performance have been proved certainly.

Even though several unexpected problems, like mostly cleaning issues, they could be solved by continuous training for field engineers and workers, and comprehensive cooperation among all participants. It was realized that efforts to understand and accommodate the field situations and schedule were also important for successful installation.

REFERENCES

[1] J. W. Shin and Y. G. Cho, “Method for a neutron guide alignment in guide cassette using a laser tracker,” Transaction of the KNS Autumn Meeting, pp. 645-646, 2008.