The Technical Scheme Optimization of Nuclear Vessel Hydrostatic Test

Zhenguo Zhang*, Huixing Feng, Weihua Zhao, Maochao Li, Xiaobing Xu, Jiuqiang Li
Suzhou Nuclear Power Research Institute Co., Ltd. Shenzhen, China

*Corresponding author: zhangzhenguocgnpc.com.cn

Abstract. Nuclear vessel hydrostatic test is an important means of sealing and pressure resistance, because the nuclear vessel hydrostatic test involves important system and key equipment, how to optimize the nuclear vessel hydraulic test is a worthy topic. This paper discusses how to optimize nuclear vessel hydrostatic test technology, mainly from three aspects to optimize, such as the optimization of working ticket logic, the optimization of vessel hydrostatic test implementation, and the optimization of hydrostatic test equipment. Optimization of hydrostatic test scheme provides significance reference for plant maintenance.

Keywords: Nuclear vessel, Hydrostatic test, optimization.

1. Introduction
During the refueling overhaul of a nuclear power plant, nuclear vessel hydrostatic test is an important part in the process of refueling overhaul. Nuclear vessels hydrostatic test uses water as medium and the test pressure is above the design pressure. As an important part of in-service inspection of nuclear power plant, hydrostatic test of nuclear power plant vessel is one of the important means to test the pressure bearing capacity of vessel.
The principle for vessels hydrostatic test is shown on Figure 1.

Fig. 1 Principle for vessels hydrostatic test
The clear technical requirements standard about the nuclear vessel hydrostatic test is described in the RSE -M PWR nuclear equipment in service inspection rules [1] and the RCC -M PWR nuclear machinery and equipment design and construction rules [2].

How to optimize the hydraulic test project is a subject worthy of further discussion. This paper mainly discusses the optimization scheme of the nuclear island vessel hydrostatic test project, which mainly introduces the optimization scheme from three aspects, that is the optimization of working ticket logic, the optimization of vessel hydrostatic test implementation, and the optimization of hydrostatic test equipment.

2. The optimization of working ticket logic
There are many cooperation works involved in the hydrostatic test, including internal and external visual inspection, gasket replacement, valve disassembly, instrument protection, cutting and welding ticket, etc., and there are many areas worthy of optimization in the corresponding schedule of cooperation.

The implementation logic diagram for vessels hydrostatic test is shown on Figure 2.

![Fig. 2 Implementation logic diagram for vessels hydrostatic test](image)

Since the internal and external visual inspection of the vessel is required to be carried out within two years before the hydrostatic test, if the hydrostatic test is arranged in a certain overhaul, the corresponding internal and external visual inspection shall be arranged as far as possible in the previous overhaul. At present, when the production plan of the power plant is scheduled, the preventive visual inspection inside and outside the nuclear island vessel of the technical department, the preventive visual inspection inside and outside the nuclear island vessel of the mechanical department, and the internal and external visual inspection within two years before the hydrostatic test of the nuclear island vessel are implemented in different time windows due to the respective plan inspection outline. This will increase the number of manholes opened and closed, resulting in increased costs. It is suggested that the planning department of the power plant should make overall arrangements for the preventive internal and external visual inspection of nuclear island vessels by the technical department during daily and overhaul periods, the preventive internal and external visual inspection by the mechanical department, and the internal and external visual inspection plan within two years before the hydrostatic test of nuclear island vessels, and arrange a unified time window on the basis of meeting the requirements of the respective plan inspection outline. The work of opening and closing the manhole once can meet the needs of three parties. This optimization method not only reduces the cost, but also reduces the work of overhaul and routine isolation overhaul. It also reduces the risk of site safety and quality, and ensures the safe and reliable operation of the unit.

Since hydrostatic test involves many works of disassembling safety valve and check valve core, if the mechanical department has corresponding off-line valve calibration work, it should be arranged in the same overhaul with hydrostatic test as far as possible.

Most of the vessels involved in the hydrostatic test are implemented in the period of low water level. The coordination work of vessels of the same type should be optimized to issue tickets together,
so that the cooperation specialty can implement relevant cooperation work at the same time, it can reduce its repeated communication work and overhaul workload.

Hydrostatic test working ticket is roughly divided into several categories. If the installation of instrument of hydrostatic test takes a long time, the PW ticket is suitable for the installation of instrument of hydrostatic test before hydrostatic test. If the installation of instrument of hydrostatic test takes a short time, general this part of the work uses the radiographic test permit ticket. The source of the water and air used test permit ticket.

The cooperation professional work ticket of hydraulic test is generally PW ticket, because PR ticket of hydraulic test occupies a large isolation boundary and many isolation boundaries valves, and there will be blocking between PW ticket and PR ticket. If it takes a long time to cooperate with the professional work order, the PW order can be issued separately before the hydrostatic test. If it takes a short time to cooperate with the professional work order, the PW order can be linked under the hydrostatic test order, so as to reduce the repeated isolation and ticket issuing work and reduce the work duration.

3. The optimization of vessel hydrostatic test implementation

Most of the hydrostatic test vessels need to cut and weld the system pipeline in order to complete the hydrostatic test. At present, the optimization scheme for the cutting and welding of the hydrostatic test mainly focuses on the optimization of the cutting size and position of the pipeline. The principle of pipeline cutting size and location optimization is to reduce the number, size and field implementation difficulty of pipeline cutting on site under the condition of meeting the field demand of hydrostatic test.

Taking the RCV001EX hydraulic test as an example, the isolation boundary of the hydraulic test has been partially extended, so that it can choose a more reasonable cutting and welding weld. The size of the weld to be cut and welded has changed from three inches to one-half inch. The space position of the site has also been greatly improved, which significantly reduces the workload of the work team. The optimization cutting position for RCV001EX hydraulic test is shown on Figure 3.

![Fig. 3 Optimization cutting position for RCV001EX hydraulic test](image)

The optimization principle of the water inlet point is as follows, the position of the flange connection or check valve under the vessel is preferred, which is conducive to the connection of the water inlet pipe and the pressure pump during the test, so as to reduce the related cutting, grinding and welding recovery work.

The optimization principle of the exhaust point is as follows, the position at the top of the vessel is selected, which is conducive to the exhaust of the gas in the vessel, and it is better to select the
position with flange connection or safety valve and check valve above the vessel, so as to install the exhaust valve and pressure gauge during the test, and reduce the related cutting, grinding and welding restoration work. Generally, the number of vent points is one, but if there is a long pipeline within the isolation boundary and the gas in the pipeline is not easy to be discharged, it is generally necessary to design relevant vent points on the pipeline to discharge the gas in the long pipeline. Because if the gas in the long pipeline cannot be completely discharged during the hydrostatic test, the gas has a greater compressibility, it will lead to the pressure rise in the process of pressurization cannot be smooth. For the poor exhaust position, it can also be extended to the better position for exhaust through the transformation of temporary special device.

The optimization of drainage path for hydrostatic test is as follows, the drainage pipeline is selected at the lowest point of the system, but the direction of some pipelines may be zigzag. In the process of drainage, the corresponding drainage path can be optimized to meet the visualization principle as much as possible, and the corresponding drainage point can be moved to the area with lower dose. The length of drainage path should be shortened as much as possible, and the number of pipeline joints should be reduced. When the drainage rate is slow, the drainage rate can be increased by the way of pressurized drainage with external air source.

4. Optimization of hydrostatic test equipment for vessels

Taking one of the temporary special devices for hydrostatic test for example, the temporary special device for hydrostatic test is shown on Figure 4.

![Fig. 4 One of the temporary special devices for hydrostatic test](image-url)

At present, the temporary special device optimization projects for hydrostatic test is as follows, the temporary special device valve at the water inlet is transformed from the corresponding needle valve to the ball valve with higher water inlet rate, which can significantly improve the water inlet efficiency. For the vessel with large volume and slow pressure relief rate, the temporary special device at the vent pressure relief position of the safety injection tank is changed from needle valve to high pressure ball valve to increase the vent rate. At the temporary special device position of the exhaust pressure gauge, a valve is added at the front of pressure gauge in order to handle the leakage of the pressure gauge seat during the pressure boosting and pressure maintaining stages. In addition, the hydrostatic test project team also designed a temporary special device integrated with water inlet, exhaust, pressure relief, pump connection and drainage, which can integrate various operations involved in the water pressure test, and it can be placed far away from the operation site for water filling and pressure boosting operation, so that the members of the working team can be far away from the radiation heat source, and it can reduce the corresponding working dose of one person. In view of the water delivery hose, the water transfer rate can be increased by improving its pressure bearing capacity and using a larger diameter hose. After prefabrication of temporary special device required for hydrostatic test, in order
to verify its sealing and availability, the optimization method is to verify it by means of pre compaction test.

The commonly used pressure pump for vessel hydrostatic test is divided into manual pressure pump and pneumatic pressure pump. The advantages of manual pump are as follows; the equipment is small in volume. Because of its light in weight, it is easy to carry on site, and the process of pressure control is better, and the rate of pressure rise is controllable. The disadvantages are as follows, the amount of water inflow is less each time, and the long-term work will lead to the fatigue of the staff. The manual pump is generally suitable for the hydrostatic test of small volume vessels. The advantages of pneumatic pump are as follows, the amount of water inflow is less each time, and the pressure rise rate is fast, it can reduce the physical labor of workers. The disadvantages are as follows, the equipment is large and inconvenient to carry, the pressure rise rate fast, and it is difficult to control. The site needs to connect to the air source. The pneumatic pump is generally suitable for the hydraulic test of the vessel with large nuclear island volume. For vessels with high test pressure, large isolation boundary and difficult pressure boosting, pneumatic pump is currently used to boost the pressure.

The physical photos of manual pump and pneumatic pressure pump is shown on Figure 5.

![Physical photos of manual pump and pneumatic pressure pump](image)

Fig. 5 Physical photos of manual pump and pneumatic pressure pump

5. Conclusions
This paper discusses the optimization scheme in the process of the implementation of the hydrostatic test project in detail. It mainly introduces the optimization scheme from three aspects that is the optimization of working ticket logic, the optimization of vessel hydrostatic test implementation, and the optimization of hydrostatic test equipment. It has certain reference significance for the engineers and technicians who have to formulate the technical scheme of the hydrostatic test and implement the hydrostatic test.

References
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