Preparation and Management of In-service Inspection Schedule Program in Nuclear Power Plants

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Abstract. In-service Inspection (ISI) schedule program for nuclear island equipment was of the important part of ISI program file system in nuclear power plants (NPPs), which acted as a connecting link. Based on ISI rules for the mechanical components of PWR nuclear islands (RSE-M) and the plant ISI general program, the preparation method for schedule program of CPR1000 units were presented. It focused on the analysis and discussion of the existing problems during the preparation, upgrade and management process and some targeted suggestions were put forward. It may lay a foundation for a further optimization of the ISI program file system and the smooth implementation of the ISI activities.

1. Induction of ISI Schedule Program

Based on nuclear safety guideline HAD 103/07[1] and the RSE-M 1997 (2000) code [2], the industry practical experiences of the domestic and foreign NPPs, the supervision requirement of the nuclear safety regulatory body and the design, installation and operation technical files, the ISI program file system was built, including the ISI general program, ISI schedule program, independent ISI program, ISI ten-year plan and ISI yearly plan. Figure 1 showed the topological graph of ISI program file system in NPPs, from which we can get the hierarchical relationship and secondary relationship. The ISI schedule program acted as a connecting link, making the ISI requirement of RSE-M 1997 (2000) code into graduation, classification, specific contents and guiding the ISI activities.

![Figure 1. Topological graph of ISI program file system in NPPs.](image-url)
1.1. Application of ISI schedule program
The ISI schedule program was written according to the requirements of the RSE-M 1997 (2000) code and ISI general program and combining the actual situation of the equipment in the nuclear power plant. It defined the inspection parts, inspection methods, inspection procedure and inspection plan of the ISI activities. From the topological graph of ISI program file system in nuclear power plant shown in figure one, the ISI schedule program is the upstream file of ISI ten-year plan and ISI yearly plan and provides two programs with the main input information.

2. Preparation method of ISI Schedule Program

2.1. Preparation Idea
Figure 2 showed the preparation method of ISI schedule program in NPPs. Preparation of ISI schedule program in nuclear power plant can be classified into four steps: definition of ISI schedule program range, collation of input files, collation of detailed information and the input of program data, which was shown in black in figure 2. In addition, the overall preparation logic was shown in red and the preparation process was shown in blue.

![Diagram of ISI schedule program preparation method]

Figure 2. Preparation methods of ISI schedule program in NPPs.

2.2. Standardized format
The inspection items and inspection requirements of mechanical equipment in nuclear island were defined in the ISI schedule program, including the list of the inspected equipment and components, the reference drawings, the inspection procedure, special tools and the inspection plan. The standardized format of the ISI schedule program was shown in table 1.

| NO. | Part to be Inspected | Reference Drawing | Weld number | NDT procedure | special tools | ISI Plan | Remark |
|-----|----------------------|-------------------|-------------|---------------|--------------|----------|--------|
| 1   | Nozzle-to-shell welds | XXX               | 6           | RT            | XXX          | XXX      | P      |
|     |                      |                   |             |               |              | P        | (1)    |
| 2   | Internal Surface     | XXX               |             | PT            | XXX          | XXX      | P      |

Remark:
(1) XXX;
Item number (NO.) is the order number of some inspection item in ISI schedule program, such as 1, 2, 3 and 4. If some item contains multiple levels inspection contents, the item numbers should be further graded, such as 1.1, 1.2, and 1.3.

Parts to be inspected are the ISI objects in nuclear island. They are determined based on the binder three appendix 3.1 in RSE-M 1997 (2000) code.

Reference Drawings included the diagrammatic drawing of the ISI object, the design drawing and the installation drawings. They are determined based on appendix 3.1 of the binder three in RSE-M 1997 (2000) code, the design drawing and the installation drawings of the nuclear island equipment.

Weld number was the amount of the ISI object only if the parts to be inspected were weld. For example, some vessel had six nozzle-to-shell welds to be inspected, the weld number was 6. If the ISI objects are not welds, no sign was needed.

NDT means nondestructive testing. It was the NDT technique used for some special ISI object. They are determined based on appendix 3.1 of the binder three in RSE-M 1997 (2000) code.

Standardized procedures are written by the inspection company according to A4800 of RSE-M 1997 (2000) code. They were used to direct the ISI activities. Before the refueling outage, the inspection company offers the procedure list with file encoding.

Special tools are the special inspection equipment and tools for ISI activities. Before the refueling outage, the inspection company offers the tool list with special encoding.

The ISI Plan was one of the most important parts in the ISI schedule program. Its purpose is to define the refueling outage cycle for some ISI item. It was usually expressed as C1, C2, and C3 et al. The letter P indicated that this ISI item would be carried out in this refueling outage cycle. For example, the nozzle-to-shell welds in table one would be inspected in C2 and C8. The ISI Plan was determined based on A3300 to A3600 of the binder one and appendix 3.1 of the binder three in RSE-M 1997 (2000) code.

Remarks were some other supplemental information for the relevant ISI item. The remark content came from the remark-instruction information in appendix 3.1 of the binder three in RSE-M 1997 (2000) code.

3. Preparation process of ISI schedule program

3.1. Definition of ISI schedule program range

ISI schedule program range is derived from the RSE-M 1997 (2000) code, the standardized schedule program is compiled with reference to A3200, B3000, C3000, D3000 and Appendix 3.1 of the binder three. Inspection components can be classified into class 1, class 2 and class 3 according to RSE-M code, and classification from inspection type includes complete ISI, partial ISI, and other in-service inspections for statutory regulated equipment.

3.2. Collation of input files

The input files mainly include system design manuals, end of manufacturing reports, design and installation drawings, and pre-service inspection (PSI) reports. For different components to be inspected, relevant input files need to be collected and preliminarily sorted. For example, the information about the shell girth welds of the main equipment of NPPs mainly involves documents such as EOMR, PSI reports, and equipment installation drawings. The girth welds of RSE-M class 2 pipelines involve documents including flow diagrams, piping isometric drawing and PSI reports. The combing of input files lays the foundation for the collation of detailed information.

3.3. Collation of detailed information

The ISI items involved in the schedule program mainly include three parts. Firstly, the five major RSE-M class 1 component, the main primary circuit and the main secondary circuit pipelines, pressure-containing accessories and safety accessories. Secondly, the girth welds, nozzle welds, support and pipe connection welds on RSE-M class 2 and 3 pipes, pumps, valves, downstream pipes and welds of orifices, pipe elbows, etc. thirdly, internal and external visual inspection and hydrostatic test for RSE-M class 2
and 3 container equipment, together with related pressure and safety accessories. For specific equipment, the following information was needed: equipment specification class, name of the inspected part, inspection content, inspection method, inspection frequency and other information. The collation of inspection items is to search and refine the ISI items one by one according to the standardized format of the schedule program. The smallest unit to be refined is the container, weld, support, and valve with 1 as the basic unit. If there are special circumstances that cannot be refined to 1 as the basic unit, the achievable degree of refinement needs to be achieved.

3.4. Input of program data
The input of program data is to enter the detailed information of the inspection items according to the standardized format in the schedule program. The entry information should be accurate, complete, standardized, and conform to the NPP document management specifications. To ensure the quality and standardization of the schedule program, the processes of compiling, checking, reviewing, and approving are generally implemented.

3.5. Main difficulties

3.5.1. Applicability of the specification. For NPPs using ASME code [3], inspection interval is 10 years, and the version remains unchanged during 10-year inspection interval. Before the new 10-year inspection interval, the latest version of the ASME Code shall be adopted in accordance with the requirements of 10CFR50.55a [4]. For NPPs using the RSE-M code, a certain version of the RSE-M code is usually used, and the version will not be changed throughout the life of the NPPs. The RSE-M code clearly specifies information such as inspection objects, inspection scope, inspection methods, and inspection frequency, which was lack of openness. With the development of science and technology, nuclear power equipment has gradually been achieving localization [5]. The processing technology, raw materials, and equipment types have changed to varying degrees from the relevant content in the RSE-M code. Especially for inspection methods, when traditional non-destructive testing methods cannot meet the requirements of on-site inspection or the radiation protection optimization principle, the non-openness of the RSE-M code is not conducive to the introduction of new NDT techniques or the use of alternative inspection techniques. Therefore, although the RSE-M code is highly operable, the applicability of the specification is inadequate due to the lack of flexibility.

3.5.2. Huge amount of input file information. As shown in Figure 2, the input files for schedule program mainly include system design manuals, EOMR, design and installation drawings, PSI reports, etc. There are thousands of upstream documents involved and tens of thousands of information in total. At the same time, there are many types of related documents and complex content. Rules for sorting out detailed information in the schedule program are various. As a result, it is necessary to be familiar with the macro layout of equipment and pipelines, as well as to query the functional parameters of equipment and pipelines, such as pipe diameter and wall thickness, material, insulation and more. The preliminary screening of detailed information can only be done through manual query, the workload was huge, and it was not easy to identify error information. In order to ensure the accuracy and completeness of the detailed information, verification was required and the entire verification process was equivalent to secondary combing. The detailed information of the preliminary query needs to be converted into a standardized format. In this process, small internet programs for data collation can be developed to improve work efficiency and information accuracy.

3.5.3. Frequent changes to input files. From the NPP design period to formal commercial operation, the upstream design documents and on-site installation documents of the NPPs were not completely certain. The isometric drawings, flow diagrams and other documents were continuously upgraded according to the requirements of the site. Information on welds, supports in the scope of RSE-M code regulation will also change. The input files used in the preparation of the schedule program are mainly
from the document system of the NPPs. It was not guaranteed that the relevant drawing files are the latest version. As a result, it was highly possible that part of the data in the schedule program does not match the actual situation on site. In view of this situation, the only way was to check the drawings with the site conditions if allowed to ensure the accuracy of the schedule program information. In addition, with the operation of a NPP, equipment, pipelines, and other components may be cancelled, updated, and retrofitted, which will also cause drawings to be updated and program data to be updated. Therefore, it was necessary to periodically upgrade the schedule program.

3.6. Maintenance and Management of schedule program
As the schedule program of a NPP unit involves specific inspection requirements for the components being inspected, it was one of the most complex documents in the program system. Maintenance and management of the schedule program included regular upgrades, content screening, information modification and comparison, and the usage of program. The amount of ISI data in the schedule program is very large, which lead many problems when managing the program in the manual mode. The most typical problems are low efficiency and insufficient accuracy. A lot of human resources were needed to maintain the inspection items and inspection plans of the schedule program. For manual management mode, not only consumed a lot of manpower and resources, but also cannot completely avoided human errors caused by mistakes. In addition, before each refueling outage, relevant ISI items were needed to be screened for preparing a ISI yearly plan. With the manual screening mode, the manual update of the program file lacks linkage. It might make the plan status in the schedule program different with the actual implementation status, which may eventually lead to inaccurate information.

With continuous increase of the number of NPPs in China, the manual management mode of the schedule programs couldn’t meet the requirements for the professionalization, standardization and informatization management. At present, domestic NPP ISI research institutions have established an ISI management system [6]. They have achieved the association of specifications, programs, components, drawings, and plans, which effectively improved the management level of NPP schedule program.

4. Summary
ISI is one of the most important measures for the safe operation of NPPs. The schedule program is an important document for the ISI work. It acts as a connecting link in the ISI program document system. A standardized preparation process was the right way to ensure the accuracy and completeness of the schedule program. In this paper, it put forward the method for preparing the schedule programs of NPP ISI activities and discussed the main problems during the process of preparing, upgrading and managing the schedule program. The establishment of a professional ISI management system can improve the management level of the NPP schedule program. It also met the multi-dimensional management requirements of NPP ISI activities.

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