

Discussion on Key Issues in the Review of Technical Specifications of China Experimental Fast Reactor

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Abstract: China experimental fast reactor is the first fast reactor. As the highest law during the operation of nuclear facilities, the technical specifications play a vital role in the stable operation of fast reactors. The review of operation technical specifications is a comprehensive review, especially for fast reactor, which is the first time in China. There are great differences between fast reactor and traditional pressurized water reactor in technology. Due to the current regulations and standards in China, most of them are formulated according to PWR. The design of the new reactor has not formed a complete standard system, especially the operation mode. The modification of the operation mode is a major modification of the operation technical specification. This paper mainly describes the core problems encountered in the nuclear safety review of the technical specifications of China experimental fast reactor, such as the operation mode, the operability of the primary circuit sodium pump, the overpressure protection system, the periodic test of the containment chamber for sodium fire and argon release accidents, and finally obtains a suitable solution. It provides technical support for the continuous development of China's fast reactor industry. The review of technical specifications for fast reactor has achieved good practical results and provided valuable experience for subsequent commercial power plants.

Keywords: Fast Reactor, Nuclear Safety Review, Discussion, Technical Specification

1. Introduction

China Experimental Fast Reactor (CEFR) is a sodium cooled pool type fast reactor with thermal power of 65 MW and electrical power of 20MW. CEFR realized grid connected power generation with 40% power in July 2011. The safety of China experimental fast reactor is ensured by the inherent safety characteristics, passive safety system and active safety system. The operation technical specification is the "law" during the operation of nuclear facilities. It specifies the technical parameters and technical requirements to be followed by nuclear facilities under normal operation, transient and abnormal conditions, mainly including safety limits, protection thresholds, operation restrictions and supervision requirements.

With the development of nuclear power in China, there is no clear technical specification for the fourth-generation reactor. At present, Chinese technical specifications mainly adopt two

modes [1]: Westinghouse standard technical specifications and legal mode technical specifications. The nuclear safety regulatory authority has been committed to unifying the technical specifications of various reactor types, so as to facilitate the follow-up regulatory policy and technical development. At the same time, it is also conducive to nuclear safety technology review. In the early technical specifications of fast reactor, many modes were involved. The operators of fast reactor would pay too much attention to many factors, which was not conducive to stable operation. There are also some unreasonable or imperfect requirements [2].

The review of operation technical specifications is a comprehensive review, especially for fast reactors, which has no reference in China. However, there are many differences between fast reactors and traditional pressurized water reactors. Therefore, more attention needs to be paid to the

review of technical specifications of fast reactors. Up to now, the review of the technical specifications of fast reactor has lasted for many years. During the review process, many key issues have been paid attention to. After several rounds of technical communication with the relevant personnel of the design, commissioning and operation of the operation unit, the nuclear safety review of the technical specifications of China experimental fast reactor has been successfully completed.

2. Status and Review Basis of Regulations and Guidelines

2.1. Review Basis

China's current regulations and guidelines should be strictly observed, including the nuclear safety law [3] and the regulations of the people's Republic of China on the safety supervision and administration of civil nuclear facilities [4]; China experimental fast reactor belongs to research reactor, which should be carried out in accordance with the requirements of research reactor design and operation safety regulations, such as research reactor design safety regulations [5] and research reactor operation safety regulations [6]; Secondly, according to the requirements of corresponding guidelines, research reactor operation management [7] and research reactor application and modification [8]; In addition, due to the preparation of technical specifications, the most important basis is the contents of relevant chapters of the final safety analysis report of China experimental fast reactor [9].

2.2. Current Situation Analysis

Due to the current regulations and standards in China, most of them are formulated according to PWR. The design of the new reactor has not formed a complete standard system. Many still refer to the design of pressurized water reactor or foreign advanced standards, such as the requirements of NUREG-1431 [10]. In other words, they are all research and experiment, which can be used as the design basis after being verified by experiments. China experimental fast reactor is a research reactor. It complies with haf202 regulations on the operation safety of research reactors and haf103 regulations on the operation safety of nuclear power plants. The format and content scope of this technical specification are also prepared with reference to the requirements of format and content of technical specification for sodium cooled fast neutron reactor.

3. Review of Implementation and Achievements

On the basis of the approved 2009 technical specification, this updated version supplements and revises the 2009 technical specification when the core residual heat removal mode under accident conditions changes with the relevant accident analysis of the original final safety analysis report

before the test verification of the natural circulation capacity of the core.

After the review of the technical specifications for China Experimental Fast Reactor (Revised Version) [11], the IAEA upgraded the technical specifications in combination with the review issues and commitments, and submitted the revised version of Chapter 17 of the final safety analysis report for China experimental fast reactor at the end of 2020, which is intended to be a reference document during operation. The contents of the report have been verified, and there are no new contents except for the implementation of previous review issues.

For the review of the 2020 revision, the reviewer believes that the applicant has revised the technical specifications meet the requirements.

4. Key Issues in Review

4.1. Operating Mode Revision and Description

In the review of the revised operation mode, the reviewer mainly reviews whether there is overlap and discontinuity between the new operation modes, and the rationality of the definition parameters of reactor status and the meaning of operation characteristics based on the problems existing in the original operation mode and the basis for the revision of the operation mode Correctness [12]. The following points are mainly concerned:

- a) Rationality of characterizing "IHX primary side inlet temperature" as reactor state

The inlet temperature at one side of the intermediate heat exchanger mixes the temperature of the hot sodium pool, and the temperature of the hot sodium pool is also affected by the three circuit and the residual discharge system of the independent heat exchanger, which cannot directly and truly reflect the core temperature, so the core outlet temperature should be used as the characteristic parameter of the operation mode. In view of the importance of core fuel assembly status, adding "core outlet temperature" as the characteristic parameter of operation mode can more comprehensively characterize the reactor status.

- b) The way of sodium insulation of main vessel

Under the cold shutdown and refueling modes, there are operating characteristics of main vessel sodium insulation, but the methods of main vessel sodium insulation under the two modes are different, and the applicant has made supplementary descriptions for the two methods in the form of notes.

- c) Speed problem of primary circuit sodium pump

Under the refueling mode, the speed of the sodium pump is less than 310rpm, but it can run at 500rpm under the component flow measurement. The reviewer believes that it is inappropriate to take the pump speed during the component measurement test as the operating characteristic under the refueling mode. The contents of the component flow measurement test conducted in refueling mode are added to the operational limits and conditions of the primary circuit

sodium pump as a special test.

At present, among the five revised modes, the conversion between each mode is more concise, which solves the problem of overlapping multiple operation modes in the past, makes it easier for operators to understand and use, and is more reasonable than the original mode.

The modification of the operation mode is a major modification of the operation technical specification. The applicant shall make a principled description and demonstration, and pay attention to the exploration and feedback of the new operation mode in combination with the practice of the operation process.

4.2. Operational Requirements for Primary Circuit Sodium Pump

Before the natural circulation capacity of the core of China experimental fast reactor has not been verified by the test, the primary circuit sodium pump must perform the safety function. Through the analysis of the anti-seismic operability of the sodium pump, the transformation of the emergency power supply system and the transformation of the access mode of the mobile power vehicle, and the management according to the safety level equipment, the primary circuit sodium circulating pump basically has the function of safety level equipment. Therefore, in the technical specifications, the corresponding operating limits and conditions are specified for the primary circuit sodium pump. The operational criteria for the sodium pump include 14 operating limits and conditions for motor, frequency converter, sodium pump, dual power switching box and mobile power vehicle. As the emergency power supply for the sodium pump, the mobile power supply truck is one of the necessary conditions to ensure the reliable operation of the sodium pump and serves as the judgment standard for the operational state of the sodium pump. In order to ensure the safety of the sodium pump, considering the conservative operation, the reactor shall be shut down first to ensure the safety of the reactor, and then the pump shall be shut down according to the situation. During accident disposal, avoid shutdown by pump shutdown.

4.3. Overpressure Protection System

The overpressure protection system is to protect the main vessel and the protective vessel from other overpressures, prevent the pressure boundary from being damaged, and provide sufficient gas cavity space to compensate for the thermal expansion of the gas in the reactor under various transitional conditions. It is designed as a safety facility system.

The status of the overpressure protection system under various operation modes can play the protection function under high pressure and low pressure. For "the overpressure protection system can operate", that is, the oil filling level of the liquid seal meets the requirements; The liquid seal is connected with the main vessel / protective vessel, and the relevant valves are opened; The periodic test meets the requirements.

4.4. Protection Setting of Safe Shutdown Earthquake

The setting value of the safe shutdown earthquake is set as SL-2 [13]. It is necessary to clarify the reason for setting the seismic setting value and whether it can provide protection for the reactor. In addition, the setting of seismic monitoring instruments (such as the location of measuring points, the seismic category of the seismic monitoring system, etc.) should be considered. Since some nuclear power plants do not introduce seismic signals into the protection system, in case of a magnitude SL-2 earthquake, the time from SL-1 to SL-2 is relatively short, and the magnitude SL-1 earthquake is the operation basis earthquake, which can ensure safe operation under the earthquake intensity, the magnitude SL-2 seismic signal of the safe shutdown earthquake is taken as the protection setting in the design.

At present, according to the development of seismic monitoring instruments, they can work under the action of earthquakes. Therefore, there is a prerequisite for entering the protection system. If the seismic signal can protect the reactor, the reactor must be stopped safely before the seismic wave reaches the reactor. The existing seismic instrument setting of CEFR cannot use SL-2 as the protection setting value and must be taken as low.

Refer to NRC guideline RG1.12 [14] and the relevant provisions of 10cfr, and considering that there is a certain margin between SL-1 and SL-2, the protection of SSE is now considered to be adjusted. Fixed value setting is modified to 120% (SL-1).

4.5. Setting Value of Delayed Neutron Protection

The setting value of delayed neutron protection is 3 times of the background. Under different reactor power conditions, the background value of neutron counting rate will change accordingly. After the core load is balanced Determine the final background data.

4.6. Sodium Fire

Various combustion modes of sodium (including spray combustion) are considered. The pressure of the primary circuit sodium pipeline is relatively low, the normal operating pressure is lower than 50kPa, and there is no obvious spraying phenomenon of sodium leakage. In addition, the primary circuit sodium leakage signal is interlocked with the shutdown of the electromagnetic pump, and the double-channel stop valve is closed to reduce the leakage.

Refer to the design of cfr600 sodium fire, psar15 of cfr600. The sodium fire combustion analysis in 6.2 [15] refers to the pool combustion superimposed with 10% fog fire combustion after sodium leakage. Use box program to calculate pool type sodium fire and feu mix program to calculate fog type sodium fire. When analyzing sodium fire, CEFR takes 10% fog fire combustion as input, which is consistent with the share of fog sodium fire in cfr600 preliminary safety analysis report.

The primary circuit sodium fire smoke exhaust system shall consider the spraying and combustion of sodium, and the

accident smoke exhaust system cannot be put into operation until the sodium combustion is terminated. The sodium pipeline is made of 316 austenitic stainless steel, with insulation layer and stainless-steel jacket laid on the surface. The pressure of the sodium circuit pipeline is low, and the leakage sodium spraying effect is not obvious compared with the high-energy pipeline. At the same time, the primary circuit sodium leakage signal is interlocked with the shutdown of the electromagnetic pump, and the pressure is relieved to reduce the leakage; Put into operation in the early stage of emergency smoke exhaust, which helps to suppress the pressure peak in the room. The review experts are further concerned about the smoke exhaust of sodium fire accident and require calculation and analysis to determine whether there will be unacceptable pressure peaks.

4.7. Periodic Test of Argon Release Accident Containment Chamber

According to the EIA report of China experimental fast reactor, the design value of room leakage rate is enveloped by serious accidents. The argon release accident includes the periodic test of the leakage rate in Room 302. The leakage in Room 302 should be required [16], and the periodic test must be carried out to prove that it can still meet the limit requirements. Reduce the leakage rate. The periodic test is tentatively scheduled to be once every three years. According to the actual situation of subsequent CEFR operation, further supplementary analysis shall be made for the periodic test of leakage rate, and the frequency of periodic test shall be fixed as far as possible.

5. Conclusion

Function Technical specifications is the top-level document for the operation of nuclear facilities and one of the most important "Regulations" for the operation of nuclear facilities, which should be strictly followed. During the review of the technical specifications of China experimental fast reactor, the operation mode, operability of primary sodium pump, overpressure protection system, setting value of safety seismic protection signal, setting value of delayed neutron protection, sodium fire, periodic test of argon release accident containment chamber and other key problems were concerned, and corresponding solutions were found.

It has achieved good practical results in the operation of fast reactor, provided guidance for the follow-up construction of high-power fast reactor, and accumulated valuable experience for the preparation and review of its technical specifications.

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