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LICENSING EXPERIENCE OF THE HTR-10 TEST REACTOR

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Abstract

A 10MW high temperature gas-cooled test reactor (HTR-10) is now being projected by the Institute of Nuclear Energy Technology within China's National High Technology Programme. The Construction Permit of HTR-10 was issued by the Chinese nuclear licensing authority around the end of 1994 after a period of about one year of safety review of the reactor design.

HTR-10 is the first high temperature gas-cooled reactor (HTGR) to be constructed in China. The purpose of this test reactor project is to test and demonstrate the technology and safety features of the advanced modular high temperature reactor design. The reactor uses spherical fuel elements with coated fuel particles. The reactor unit and the steam generator unit are arranged in a "side-by-side" way. Maximum fuel temperature under the accident condition of a complete loss of coolant is limited to values much lower than the safety limit set for the fuel element. Since the philosophy of the technical and safety design of HTR-10 comes from the high temperature modular reactor design, the reactor is also called the Test Module.

HTR-10 represents among others also a licensing challenge. On the one side, it is the first helium reactor in China, and there are less licensing experiences both for the regulator and for the designer. On the other side, the reactor design incorporates many advanced design features in the direction of passive or inherent safety, and it is presently a world-wide issue how to treat properly the passive or inherent safety design features in the licensing safety review.

In this presentation, the licensing criteria of HTR-10 are discussed. The organization and activities of the safety review for the construction permit licensing are described. Some of the main safety issues in the licensing procedure are addressed. Among these are, for example, fuel element behaviour, source term, safety classification of systems and components, containment design. The licensing experiences of HTR-10 are of great reference value for the modular reactor concept.

1 Introduction and Background

Presently, a 10MW high temperature helium cooled test reactor (termed HTR-10) is being projected by the Institute of Nuclear Energy Technology (INET) of Tsinghua University. The reactor will be erected on the site of INET which is about 40km to the north of Beijing city. The HTR-10 test reactor is a major project in China's High Technology Programme.

The HTR-10 test reactor uses spherical fuel elements which are made completely of ceramic materials. Uranium dioxide as nuclear fuel is in the form of coated particles which are dispersed in the graphite matrix of the fuel elements. Graphite serves as neutron moderator and reflector as well as the main structural material of the reactor core, so that the reactor has a practically full-ceramic core which has a large heat capacity and is high-temperature-resistant. As coolant serves the inert gas helium which causes practically no corrosion problems and plays no part in the reactor neutron balance.

For the HTR-10 test reactor, decay heat removal does not rely at all on any active cooling systems. At a complete loss of coolant accident, the maximum fuel temperature remains under the limit value with a big margin. Reactor shut down systems are placed only in the side reflector. No control rods would have to be inserted into the pebble bed so that damages to the fuel elements are avoided. The reactor unit and the steam generator unit are arranged in a so-called "side-by-side" way, so that the reactor and the steam generator can be easily isolated from each other under accident conditions in order to protect the ceramic core of the reactor and the metallic structure of the steam generator. These design features of the HTR-10 test reactor represent the advanced modular design of high temperature gas cooled reactors (HTGR).

In terms of reactor types, HTR-10 is the first of its kind to be built in China. Besides, the reactor design incorporates many advanced features in the direction of passive safety. From these points of view, the HTR-10 reactor represents a big licensing challenge both to the regulator and to the applicant. On the one side, there exist not enough standards, codes and guides in China directly applicable to gas cooled reactors. And on the other side, it is now a world-wide problem for regulators how to properly treat passive features in the advanced reactor designs. In the next sections, the settlement of the main safety issues in the licensing procedure will be addressed.

For the licensing of the construction permit (CP) of the HTR-10 test reactor, the licensing authority is the National Nuclear Safety Administration (NNSA) which is technically backed up by Suzhou Nuclear Safety Center and Beijing Nuclear Safety Center. The applicant is the Institute of Nuclear Energy Technology of Tsinghua University.

2 Regulatory Criteria

As stated above, up to now there exist in China not enough nuclear standards, codes and guides specifically compiled for high temperature gas cooled reactors which are directly applicable to the HTR-10 reactor. Before the CP licensing started, two documents had been compiled under the organization of NNSA: Design Criteria for the 10MW High Temperature Gas-cooled Test Reactor[1] and Standard Content and Format of the Safety Analysis Report of the 10MW High Temperature Gas-cooled Test Reactor[2], which were supposed to serve as the licensing basis of the test reactor. In the actual licensing procedure, stronger reference is made to the second document than to the first one.

From the nuclear point of view, the HTR-10 reactor is much smaller than nuclear power plant reactors since its thermal rating is only 10MW. The main purpose of the reactor project is to test and prove its main technical and safety features rather than to provide commercial power. But HTR-10 has not been regarded as a research reactor because the overall purpose of the reactor is to test power generation technology. Based on the above considerations, following principal guidelines have been followed in the licensing procedure concerning what standards and/or codes are taken as licensing basis or references:

- As top level regulatory criteria, the nuclear safety related standards, codes, regulatory guides issued by NNSA (HAF series), which covers site selection of nuclear power plants (NPP), design of NPP, quality assurance of NPP, etc., should serve as fundamental basis for licensing criteria.
- References are made to international and foreign standards, codes and guides, e.g. of USA (RG series, ASME, General Design Criteria of High Temperature Gas Cooled Reactors), of Germany (KTA Regeln) and of France (RCC series).
- HTR-10 deserves special treatment in specific cases considering its lower power rating, its nature as a test reactor and especially its designed inherent safety features.

3 Licensing Activity and Procedure

3.1 Pre-application activities

Since the HTR-10 test reactor is the first high temperature helium cooled reactor to be built in China, there are less experiences both from the regulator side in licensing and from the applicant side in design. Therefore, there had been many interactions between the licensing experts and the design engineers in the form of e.g. seminars given by the design engineers to introduce the HTR-10 design and general features of high temperature gas cooled reactors to the licensing experts. These communications helped the involved personnel to exchange ideas and opinions on an early stage.

As mentioned above, NNSA had organized to establish technical documents [1,2] before the licensing procedure started. The second document, namely the Standard Content and Format of the Safety Analysis Report of the 10MW High Temperature Gas-cooled Test Reactor, which defines the content framework of the Preliminary Safety Analysis Report of the 10MW High Temperature Gas-cooled Test Reactor (PSAR)[3], has guided the compilation of the document.

Following the principle of "earlier involvement", some licensing staff had been involved in some pre-application work such as in the site selection activities to assure a more smooth licensing procedure.

Before the licensing procedure started, the applicant had got the HTR-10 project approval from the State Education Commission and the approval of the Feasibility Study Report of HTR-10 from the State Science and Technology Commission. The "Environmental Impact Report of the 10MW High Temperature Gas-cooled Test Reactor" had been approved by the State Environmental Protection Administration.

3.2 Licensing activities and procedure

The application for the Construction Permit of HTR-10 was submitted to NNSA in December 1993 with the attached documents, of which the PSAR[3] and the Quality Assurance Programme of the 10MW High Temperature Gas-cooled Test Reactor (for Design and Construction Periods) (QAP)[4] are the main technical documents to be reviewed by the licensing personnel. From then on the licensing procedure started formally and lasted for one year. The applicant, namely the Institute of Nuclear Energy Technology, got the Construction Permit in December 1994.

The licensing procedure goes with the following main activities undertaken:

- The reviewers (licensing personnel) raise technical questions in written form. Altogether, more than 700 questions were raised on PSAR and QAP in several batches.
- The raised questions are answered by the HTR-10 design engineers in written form.
- Meetings are held between reviewers and design engineers to discuss and address technical questions and issues. During these meetings, clearances or solutions to some questions or problems are found, or agreements upon some technical issues are reached. Unresolved issues are documented in the form of so-called work-sheets. These work-sheets are worked on further by the designers for further interactions.
- Topical meetings are held between reviewers and design engineers on some special issues in site selection, digital protection system design, quality assurance.
- The Nuclear Safety Expert Committee is consulted about some special issues and about the overall evaluation of the licensing personnel of the HTR-10 test reactor on the CP application stage.
- The licensing authority finally reaches a favorable Safety Evaluation Report which leads to the issuing of the construction permit of the HTR-10 test reactor.

4 Main Licensing Safety Issues

4.1 Fuel elements

The designed passive safety features of the HTR-10 test reactor are fundamentally based on the excellent fission product retaining capability of the fuel elements. For all the reasonably postulated accidents, both within the design basis and beyond that, radioactive nuclides are retained in the fuel elements well enough so that unallowable radioactive release into the environment will not take place. Therefore, it has been a core issue during the licensing to make sure whether the fuel elements used for the HTR-10 reactor will really behave as good as they are designed for. It is planned that sample fuel elements are to be irradiated to designated conditions covering burn-up, fast neutron dose and irradiation temperature before the fuel elements are operated in the real reactor to those conditions. An oxidation test of the fuel elements under severe accident conditions is also planned to be made.

4.2 Source term

A mechanistic methodology is adopted for determining the radioactive source term. Severe core damages are not arbitrarily postulated, as it is done for large water cooled power reactors, where large amount of radioactivity would have to be postulated to be released out of fuel elements due to severe core damages, and which would lead to the requirement of a pressure-containing and leak-tight containment design.

The release of radioactivity is calculated specifically for those individual demanding accidents which lead to the most release of radioactive nuclides from the fuel elements. The release of radio-nuclides from the fuel kernel through the surrounding coatings and the matrix graphite to the helium coolant is calculated on a diffusion-sorption basis, where the selection of calculation parameters is based mostly on the German experimental results and literature. Where necessary, conservative factors are put into the analysis.

4.3 Accident analysis

As usual, design basis accidents (DBA) are classified in several categories. These are:

- increase of heat removal capacity in primary circuit
- decrease of heat removal capacity in primary circuit
- decrease of primary flow rate
- abnormality of reactivity and power distribution
- rupture of primary pressure boundary tubes
- anticipated transients without scram (ATWS).

The reactor is designed against these accidents. The analysis of these accidents is done with conservatism. The analysis results show excellent safe response of the reactor to accidental events. Within the framework of DBA, no accident would lead to relevant release of fission products from the fuel elements.

Great attention and effort has been given to the treatment of severe accidents. A number of highly-hypothetical postulated accidents are selected to be analyzed. These hypothetical events mainly include:

- long-term failure of the reactor cavity cooling system
- simultaneous withdrawal of all control rods at power operation and at reactor start-up
- failure of the helium circulator shut-down
- simultaneous rupture of all steam generator tubes.
- rupture of the cross duct vessel

In selecting these severe accidents, reference is made to the licensing experience of MHTGR in USA[5] and of HTR-Modul in Germany. The analyses of severe accidents show that under these highly-hypothetical circumstances, severe damages to the fuel elements would not be expected which would lead to impermitted release of radioactivity into the environment.

4.4 Safety classification

Because the HTR-10 test reactor is designed on the inherent safety philosophy, safety classifications of systems and components departure from the way it is done for water cooled power reactors. For example, primary pressure boundary is defined to the first isolation valve. Steam generator tubes are classified as Class II component. Diesel generators are not required to be as highly qualified as those used for large water cooled power reactors, since no systems or components with large power demand would require an immediate start of the diesel engines at a plant black-out accident.

4.5 Containment design

Based on the characteristics of inherent safety of the HTR-10 test reactor, no pressure-containing and leak-tight containment is designed. The concrete compartments, which houses the reactor and the steam generator as well as other parts of the primary pressure boundary and which is preferably called as confinement, together with the accident ventilation system, serve as the last barrier to the radioactivity release into the environment. During normal operation, the confinement is ventilated to be kept sub-atmospheric. When the integrity of the primary pressure boundary is lost, the primary helium coolant is allowed to be released into the environment without filtering because of its low radioactivity content. Afterwards the confinement is ventilated again, gases in it will be filtered before they reach the environment.

5 Summary

The licensing activities of the construction permit of the HTR-10 test reactor are overall well organized in a rather tight time-framework. The evaluation of the licensing body on the safety favorites the reactor safety design and has led to the issuing of the construction permit of the HTR-10 test reactor.

Experiences in licensing HTR-10 are of great reference value for the modular concept of high temperature gas cooled reactors. The main safety issues would be roughly the same with the modular concept and the methodology used in licensing the HTR-10 should be to great extent applicable when licensing a modular power reactor.

REFERENCES

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