4. Outline of Examination Guides of Water-Cooled Research Reactors in Japan

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ABSTRACT

The Nuclear Safety Commission of Japan published two examination guides of water-cooled research reactors on July 18, 1991; one is for safety design, and another is for safety evaluation. In these guides, careful consideration is taken into account on the basic safety characteristic features of research reactors in order to be reasonable regulative requirements. This paper describes the fundamental philosophy and outline of the guides.

INTRODUCTION

Since most research reactors in Japan were constructed in 1960's, some of these are recently required modification to accomodate changing needs of research and experiments or to take countermeasures for ageing of reactor facilities. In addition, high enriched fuel are being replaced with low enriched one, which requires re-evaluation for core safety. Considering these situations, the Nuclear Safety Commission decided to establish safety examination guides of research reactors and started the works at the Special Committee on Safety Standard of Reactors in January 1988.

After three and a half years deliberation, the Commission approved and published two guides; Examination Guide for Safety Design of Water-Cooled Type Research and Testing Nuclear Reactor Facilities (hereinafter to be referred as the Guide for Safety Design of Research Reactors), and Examination Guide for Safety Evaluation of Water-Cooled Type Research and Testing Nuclear Reactor Facilities (hereinafter to be referred as the Guide for Safety Evaluation of Research Reactors). The Guides are to be used as general evaluation guides for examining appropriateness of the safety design principles and safety evaluation, respectively, of a proposed research reactor facility in response to the application of installation license (including amendments).

As the fundamental policy for establishing the Guides, the following characteristic features of research reactors were taken into consideration, comparing with power reactors.

1) Diversity of reactor structure, thermal output and operational features
2) Lower coolant energy and simpler cooling system due to low coolant temperature and pressure
3) Lower thermal output and small fission product inventory

4) Larger reactivity worth of fuel assembly and higher power density in case of high output reactor
5) Short operating duration period and accessibility to the system and components for inspection and maintenance.

Concerning power reactors in Japan, guides for safety design and safety evaluation of light water nuclear power reactor facilities were established in 1970's. Revision works for the guides of power reactors had been in progress when the works for research reactors started. Accordingly, in establishing the Guides of Research Reactors, consideration were also taken into to be compatible with the guides of power reactors. Thus the Guides of Research Reactors were established with consideration of the characteristic features and accumulated experiences and knowledge on the experiments and operation of research reactors, and also based on the latest technology.

SCOPE OF THE GUIDES

The both Guides apply to the safety examination of the reactors which are used for research and/or testing, cooled by water and operated with constant power (hereinafter to be referred as research reactors). For other reactors such as pulse reactor and critical assembly, the Guides may be referred to except specific matters derived from water-cooled type or those intrinsic plant features.

CLASSIFICATION OF RESEARCH REACTORS

In the Guides, the research reactors are classified into following three groups depended on the reactor thermal output, in order to be reasonable for the requirements of the Guides.

1) Low output reactor (under 500 kW)
2) Middle output reactor (not less than 500 kW, under 10 MW)
3) High output reactor (not less than 10 MW, not higher than 50 MW)

This classification is based on the differences on the importance of decay heat removal in abnormal conditions and the amount of radioactivity release to be postulated in accident conditions. The articles of the Guide for Safety Design may apply in accordance with the importance of the safety function of the respective group. For the reactors higher than 50 MW, there may be matters which cannot be covered by the Guides. For these matters, the guides of power reactors may be referred to.

GUIDE FOR SAFETY DESIGN OF RESEARCH REACTORS

The Guide for Safety Design of Research Reactors is to be used as a general evaluation for examining the appropriateness of the safety design principles of a proposed research reactor. The Guide is mainly composed of definition of words, fifty articles and interpretation of the articles. In addition, "Fundamental Principles for Classification of Safety Function Importance of Water-Cooled Research

Reactors and Its Supplement", which are to be described in the next section, are attached in the Guide.

The articles are grouped into ten, as follows. In the parentheses, a number of articles are shown.

1) Overall Requirements(10)
2) Reactor and Reactor Shutdown System(10)
3) Reactor Cooling System(5)
4) Reactor Building and Experimental Facility(2)
5) Safety Protection System(6)
6) Control Room and Its Related Facility(4)
7) Instrumentation and Control System and Electric Power Supply System(2)
8) Fuel Handling System(3)
9) Radioactive Waste Disposal Facility(4)
10) Radiation Control(4)

Noticeable matters of this Guide are as follows.

- A concept and article on "Testing Fuel Assembly" are introduced in order to enable to carry out in-core testing on cladding failure or partial melt of fuel meat for the purpose of research and development of fuel.
- For emergency core cooling, the definition and articles on "Core Submersion Keeping System" are clarified.
- The concepts of coolant pressure boundary and containment vessel of Light Water Reactors (LWRs) are excluded because the coolant energy and radioactivity inventory of the research reactors are much lower than those of LWRs.
- Requirements for low and middle output reactors are generally lightened.

FUNDAMENTAL PRINCIPLES FOR CLASSIFICATION OF SAFETY FUNCTION IMPORTANCE

This Fundamental Principles supplements to the Guide for Safety Design to clarify the construction of the safety function importance described in the Guide. That is, safety-related buildings, systems and components are classified into the specified safety importance grades which imply respective design requirements. The constitution, definition and requirements of the fundamental principles are almost the same as those of LWRs in order that the criterion of judgement may be clarified in comparison with that of LWRs. However, consideration on special features of the research reactors appears in the examples of the classification which is attached in the Fundamental Principles.

In the first stage of the Fundamental Principles, safety-related equipment is devided into two groups; Prevention System(PS) whose loss of function may cause an abnormal condition resulting excess exposure to the public or workers, and Mitigation System(MS) whose function prevents the enlargement of abnormal conditions and mitigates the excess exposure. In the next stage, the equipment belonged to PS and MS is classified into Class 1 to Class 3, respectively, which imply the respective basic design targets to be accomplished by the established technology of design, construction and testing, and operational management, as follows.

Class 1: to assure reliability as high as reasonably achievable

Class 2: to assure high reliability
Class 3: to assure reliability equal to or higher than the general industrial facilities.

In the attached examples of the classification, most safety equipments are classified into Class 2 and Class 3 except only a part of those of high output reactors.

GUIDE FOR SAFETY EVALUATION OF RESEARCH REACTORS

The Guide for Safety Evaluation of Research Reactors is prepared as a general criterion for examining the appropriateness of safety and site evaluation of a proposed research reactor. The Guide is consisted of three parts; the text, interpretation and supplement. The text describes, for both safety and site evaluation, scope to be evaluated, selection of events to be evaluated, judgement criteria of the evaluation and features to be considered in the analysis. In the supplement, the concrete events, conditions of analysis and criteria to be applied to the respective selected events are described. The consideration on safety evaluation of critical assemblies is attached as a reference in the interpretation.

I. Safety Evaluation

In order to confirm the adequacy of safety design principles, it is necessary to evaluate abnormal conditions which are "Abnormal Transient during Operation" and "Accident". The events of Abnormal Transient during Operation include the conditions resulting from a single failure of equipments or a single operator error anticipated to occur during the reactor life time. The events of Accident include the conditions which are beyond those of Abnormal Transient during Operation, and to be postulated from the view point of safety evaluation of the reactor facility because of the possible release of radioactivity, though the frequency of those occurrences is smaller than that of Abnormal Transient during Operation. In the Guide, internal events are to be evaluated because the adequacy of countermeasures for external events due to natural phenomena or external human events are evaluated in the Guide for Safety Design.

For safety evaluation, the representative events are selected as follows.

1. Abnormal Transient during Operation
   (1) abnormal changes of reactivity or power distribution in the core
   (2) abnormal changes of heat generation or heat removal in the core
   (3) other events depended on the design features of the reactor facility

2. Accident
   (1) abnormal reactivity insertion
   (2) flowing out of reactor coolant or remarkable change of core cooling conditions
   (3) abnormal release of radioactivity to the environment
   (4) other events depended on the design features of the reactor facility

Judgement criteria for safety evaluation are as follows.

1. Abnormal Transient during Operation

In the events, the core shall not exceed the permissible design limits of fuel, and the reactor facility shall be restored to the normal operation. That is,
   (1) minimum critical heat flux shall over the permissible design limit, and
   (2) fuel cladding shall not fail mechanically.

2. Accident

In the events, the core shall not melt or not be damaged remarkably, and any secondary damages to cause other abnormal events shall not occur, thus the adequacy of the design of radioactivity barrier shall be confirmed. That is,

(1) *fuel shall not generate mechanical energy in occurrence of fuel failure,*
(2) core shall not be remarkably damaged, and shall maintain enough coolability, and
(3) risk of radiation exposure of the public shall not be remarkable.

Features to be considered in the analysis are mainly as follows.

(1) Initial conditions of the core shall be selected so that the result of analysis is the severerst for the judgment criterion.
(2) Safety functions to be considered in the analysis shall be of MS-1 and MS-2, and shall be assumed a single failure of each system, adding the event, of reactor shutdown, core cooling and radioactivity enclosure so that the result of analysis is the severest.
(3) Adequate time margin shall be considered for operator manual action which is necessary to mitigate the effect of the event.
(4) Adequacy of the computing programs shall be demonstrated, and the model and parameters shall be selected so that the result is severe.

II. Site Evaluation

Appropriateness of the reactor siting condition is examined based on "Examination Guide for Reactor Siting and Guideline for Interpretation in Their Application" (hereinafter to be referred as the Guide for Reactor Siting), while, for the reactor whose thermal output is less than 10 MW, this is used as a reference. The Guide for Reactor Siting requires that radiation exposure of the public in "Major Accidents" and "Hypothetical Accidents" shall be under the respective guideline.

In the Guide for Safety Evaluation, the evaluation of Major Accidents and Hypothetical Accidents are required without regard to the thermal output, and the judgement criteria are cited those of the Guide for Reactor Siting. In selecting Major Accidents, the Accidents which have the possibility of causing spread of radioactive materials are evaluated, then the maximum release of radioactive material is postulated from a technological point of view. For Hypothetycal Accidents, more release of radioactive material is postulated in the selected Major Accidents. In the analysis of Major Accidents and Hypothetical Accidents, evaluation shall be performed based on the philosophy of the Guide for Reactor Siting.

As a typical Major Accident of high and middle output reactors used plate type fuel, a coolant channel blockage accident is selected, and for reactors used rod type fuel, a fuel failure accident to occur release of fission product in the fuel gap is referred. These are resulted from study on the experienced fuel failures including overseas research reactors.

CONCLUDING REMARKS

In establishing the Guides, efforts were made on the optimization of securing safety and applying the specific features of the existing diverse research reactors. A partial nonconformity with the Guides in a proposed reactor facility is permitted if the nonconformity is based on a technological progression. Thus the Guides should be adequately revised to take in the technological progression.