Requirement and Prospect of Nuclear Data Activities for Nuclear Safety

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Owing to continuous efforts by the members of JNDC (Japanese Nuclear Data Committee) and Nuclear Data Center in JAERI (Japan Atomic Energy Research Institute), several superb evaluated nuclear data files, such as JENDL, FP (fission product) yields and decay heat, have been compiled in Japan and opened to the world. However, they are seldom adopted in safety design and safety evaluation of light water reactors and are hardly found in related safety regulatory guidelines and standards except the decay heat. In this report, shown are a few examples of presently used nuclear data in the safety design and the safety evaluation of PWRs (pressurized water reactors) and so forth. And then, several procedures are recommended in order to enhance more utilization of Japanese evaluated nuclear data files for nuclear safety.

1. Introduction

At present, 51 light water reactors produce about 1/3 of electricity in Japan, and a new fuel reprocessing plant is now being constructed in Rokkasho-mura. However, successively occurred accidents, particularly the most recent one at a fuel conversion plant of JCO, Inc. in Tokai-mura, must have increased anxiety on nuclear energy in many people's mind. Japanese nuclear energy is at a crisis. We ought to overcome this situation by making efforts for improvement in nuclear safety and for recovery of reliability on nuclear energy. It seems quite difficult to do this, yet nuclear energy itself is essentially important not only for national prosperity, but also for reservation of global environment in the 21st Century.

The activities in nuclear science and engineering in Japan have reached the top level in the world, but many scientists and engineers are now inclined to too specialized by losing common sense and curiosity to other fields. Most of plant engineers and workers in nuclear industries hardly try to get new informations in nuclear science and engineering. The JCO accident was occurred in the very same village where beautiful transient experiments were carried out for simulating criticality accidents of aqueous fuel solution using TRACY of the NUCEF facility at JAERI. It is regrettable that there is estrangement between research institutes and manufacturing plants in Japanese nuclear energy.

Similar tendency can be seen in the field of nuclear data in Japan. Owing to continuous

efforts by the member of JNDC and Nuclear Data Center in JAERI, several superb evaluated nuclear data files, such as JENDL, FP yields and decay heat, have been compiled. However, these evaluated nuclear data are seldom adopted in safety design and safety evaluation of light water reactors even now. They are hardly found in related safety regulatory guidelines and standards except the decay heat. Very recently, the staff of JAERI didn't use the FP yields data of JNDC, but German ones for the measurement of the FP densities in the precipitation tank at the conversion plant of JCO. In this report, shown are a few examples of presently used nuclear data in the safety design and safety evaluation of PWRs and so forth. Thereafter, several procedures are recommended in order to enhance more utilization of Japanese evaluated nuclear data files for nuclear safety.

2. Legal Regulations for Safety of Power Reactors and Nuclear Facilities

By the Law Concerning Regulation of Nuclear Raw Material Substances, Nuclear Fuel Substances and Nuclear Reactors, establishment of a nuclear reactor and enterprise of a nuclear fuel facility must be permitted by Japanese Government. The procedure from site selection to commencement of operation for a nuclear power reactor is depicted in Fig.1[1]. In the procedure the safety examination organization of nuclear facilities is shown in Fig.2[1]. In the attachments of the application for permission of the establishment of a nuclear reactor, nuclear data are required in the following 3 articles:

(1) Explanation about the safety design of reactor facilities (Attachment No.8),
(2) Explanation about the control of exposed radiation doses caused by nuclear fuel and by substances contaminated by it, and about the disposal of radioactive wastes (Attachment No.9)
(3) Explanation about the type, the degree, the influence etc. of reactor incidents and accidents assumed to occur by misoperations, faults of machines and instruments, earthquake, fire and so forth (Attachment No.10, safety evaluation).

For the safety examination of a light water reactor, Nuclear Safety Commission have decided several safety regulatory guidelines and reports of related rules. Among them the following 2 items include nuclear data:

(1) Regulatory guideline for the evaluation of an emergency core cooling system (ECCS),
(2) Energies of radiations for the calculation of exposed doses.

In the first one, the recommended values of the decay heat by JNDC is adopted as a heat source, but their newly evaluated nuclear decay data are not found in the second one.

After getting the permission of the establishment of a reactor, the enterpriser has to apply for the sanction of its construction plan to the Government. In this application, nuclear data are required in the following 5 items:

(1) Thermal power calculation,
(2) Control capability calculation,
(3) Explanation about nuclear fuel substances not reaching criticality in new fuel racks,
(4) Explanation about nuclear fuel substances not reaching criticality in spent fuel racks,

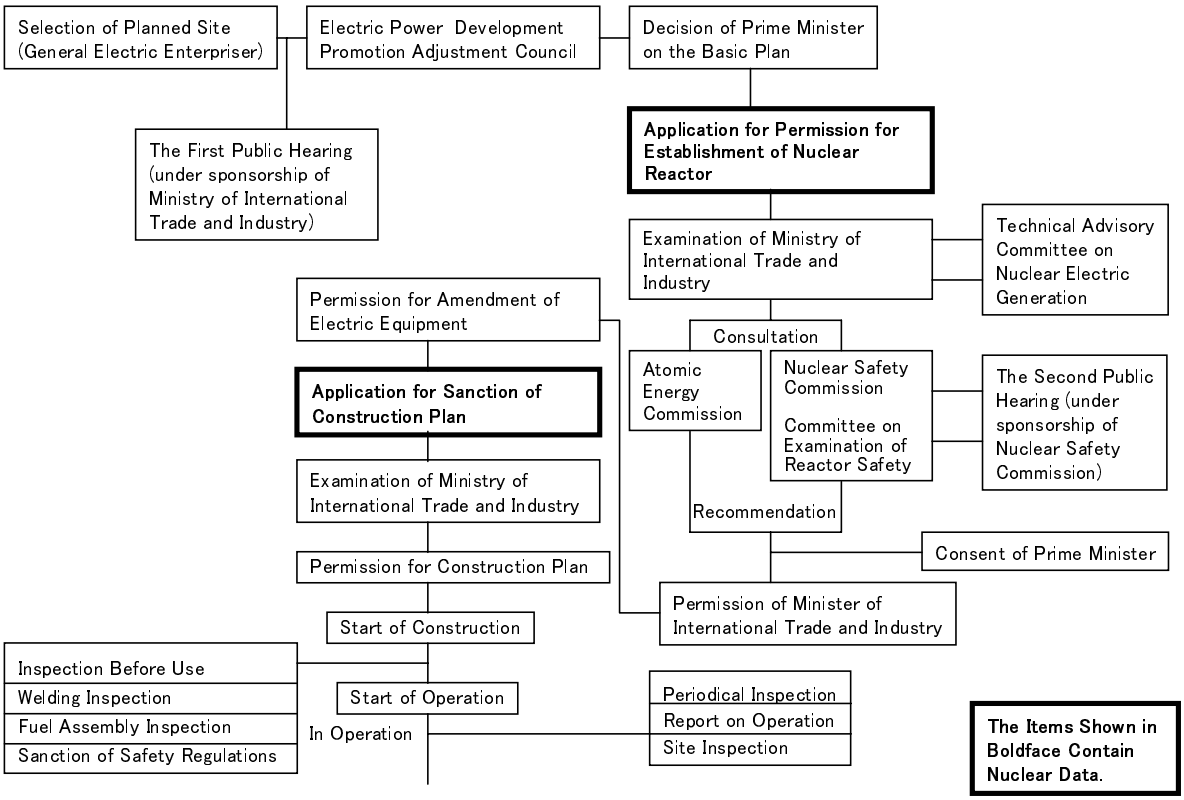

Fig.1 Procedure from site selection to commencement of operation for a nuclear power reactor

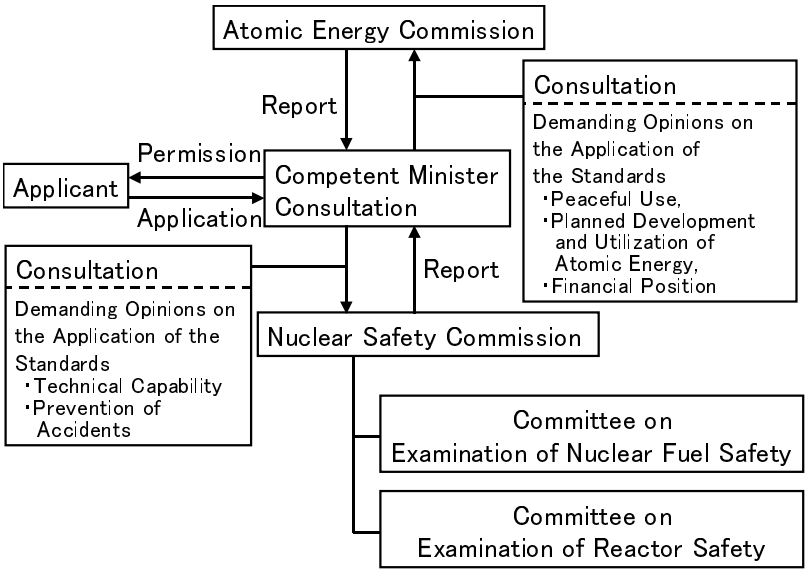

Fig.2 Safety examination organization of nuclear facilities

(5) Calculation of radiation shielding and heat removal of biological shields.

Three regulatory guidelines have been determined for the safety examination of nuclear fuel facilities as follows:

(1) Basic regulatory guideline,
(2) Regulatory guideline for fabrication facilities of nuclear fuel,
(3) Regulatory guideline for reprocessing plant of spent fuel.

In these guidelines, no nuclear data are given explicitly.

3. Some Examples of Recent Nuclear Data Utilization in Safety Examination of Nuclear Facilities

In Table 1, shown are the nuclear data recently used in safety design and safety evaluation of PWRs. It is seen that a few American nuclear data in commercial calculation codes are mainly used except the recommended values of the decay heat by JNDC. Relatively old evaluated nuclear data, ENDF/B IV, is still used for radiation shielding calculation.

As the FP yields, not JNDC data but those by Meek and Rider in 1974 are used for the safety evaluation of a full mixed oxide (MOX) core of advanced boiling water reactors (ABWRs).

In the attachment of the application for the permission of enterprise of the conversion plant in JCO, they adopted the Hansen-Roach 16 group constants in KENO IV for the calculation of subcriticality. Very recently, the staff of JAERI didn't use the FP yields data of JNDC, but those in Chart of Nuclides by Seelmann et al. for the measurement of the FP densities in the precipitation tank at the conversion plant in JCO.

Evaluated nuclear data are similar to commercial goods, and hence they must be utilized by customers. Lack of "business activities" to promote their more uses is strongly pointed out for nuclear safety, although this review is not very thorough but only showing a few examples.

4. Recommendation to Enhance More Utilization of Japanese Evaluated Nuclear Data for Nuclear Safety

In order to enhance more utilization of Japanese evaluated nuclear data for nuclear safety, the following procedures may be recommended:

(1) Careful survey of nuclear data "market" in the fields of nuclear safety, especially for light water reactors and nuclear fuel facilities.
(2) Making efforts for Japanese evaluated nuclear data to be adopted in safety design and safety evaluation of light water reactors and nuclear fuel facilities. More active works, such as execution of these calculations using JENDL by themselves, are required, otherwise no change can be expected.
(3) Making efforts for Japanese evaluated nuclear data to be adopted in safety regulatory guidelines which are used for the safety examination of nuclear facilities, as the case of the decay heat.
(4) Making efforts for Japanese evaluated nuclear data to be adopted in technical standards of Atomic Energy Society of Japan (AESJ) etc. as well as those of ANSI, ASTM and so forth.

Table 1 Nuclear data recently used in safety design and safety evaluation of PWRs

Item	Required Nuclear Data	Analytical Codes ／ Method	Nuclear Data	Necessity of Nuclear Data Improvement	Remarks
Core Design Reactor Establishment Application *1, Att.8 [Core Nuclear Design]	Neutron Cross Sections (σ_{tr}、σ_a、σ_f、σ_s) κ、ν Decay Constant Fission Spectrum Fission Yield Branching Ratio	・PHENIX-P ・ANC	ENDF/B-V	・Present data are sufficient in the practical use for safety design and evaluation. ・In general, improvement of data is preferable.	
Sub-Criticality Calculation for Spent Fuel Pit Reactor Establishment Application *1, Att.8 [Sub-criticality design]	Neutron Cross Sections (σ_{tr}、σ_a、σ_f、σ_s) ν Decay Constant Fission Spectrum	・PHOENIX-P ・HIDRA	ENDF/B-V		
Decay Heat Evaluation for Spent Fuel Pit Reactor Establishment Application *1, Att.8 [SFP Cooling System Design]	Decay Energy Decay Constant Fission Yield Branching Ratio	・AESJ Recommended data (Decay Heat from FP) ・ORIGEN2 (Decay Heat from Actinides)	・JNDC-V2 ・ORIGEN Library	・Ditto ・Use of the same library is preferable in both FP and actinides decay heat evaluations .	The use of AESJ's decay heat data is approved in the NSC's regulatory guide for ECCS evaluation.
Evaluation of Radioactivities in Reactor Coolant Reactor Establishment Application *1, Att.9,10 [Dose Evaluation during Normal Operation] [Dose Evaluation during Accident]	Decay Constant Fission Yield Neutron Absorption Cross Section σ_a (Xe-135)	Equations in the NSC's regulatory guide for dose evaluation during Normal Operation	・Data shown in NSC's Report ・2.65×10^{6} barn	・Present data are sufficient in the practical use for safety design and evaluation. ・In general, improvement of data is preferable.	
Safety Analysis (Kinetic Calculation) Reactor Establishment Application *1, Att.10 [Safety Evaluation]	Effective Delayed Neutron Fraction Prompt Neutron Lifetime	Transient Analysis Codes (MARVEL, etc)	Keepin's Data(β) (ENDF/B-V)	・Present data are sufficient in the practical use for safety design and evaluation. ・In general, improvement of data is preferable.	Core average values are calculated by PHENIX-P／ANC using ENDF/B-V and Keepin's data., and used as input for kinetic calculations by transient codes.
Core Decay Heat Evaluation Reactor Establishment Application *1, Att.10 [Safety Evaluation]	Decay Energy Decay Constant Fission Yield Branching Ratio	・AESJ Recommended data (Decay Heat from FP) ・ORIGEN2 (Decay Heat from Actinides)	・JNDC-V2 ・ORIGEN Library	・Ditto ・Use of the same library is preferable in both FP and actinides decay heat evaluations .	The use of AESJ's decay heat data is approved in the NSC's regulatory guide for ECCS evaluation.
FP Inventory Calculation Reactor Establishment Application*1, Att.10 [Dose Evaluation During Accidents]	Fission Yield Decay Constant Branching Ratio	・Equation shown in the application Report(simple production-decay balance equation)	・Data shown in NSC's Report ・TABLE OF ISOTOPES, 6th edition	・Present data are sufficient in the practical use for safety design and evaluation. ・In general, improvement of data is preferable.	
Radiation Transportation Calculation Construction Plan Application *2 [Radiation Shield Design]	Neutron Cross Sections (σ_{tr}、σ_a、σ_f) Secondary γ-ray Production Cross Section Neutron Spectrum γ-ray Spectrum	・Point Attenuation Kernel Codes ・Transportation Calculation Codes	ENDF/B-IV		

*1: Formally called "Application for Permission for Establishment of Nuclear Reactor"

*2: Formally called "Application for Sanction for Construction Plan"

(NSC: Nuclear Safety Commission、AESJ: Atomic Energy Society of Japan)

(5) Publication of handbooks, tables and charts of Japanese evaluated nuclear data, and their wide distribution by the Internet.
(6) Survey of nuclear data used in essential textbooks on reactor physics, radiation protection and shielding and nuclear safety. If these data seem to be insufficient or imprecise, make contact with the authors or the translators and ask them to revise these data.
(7) Publication of a new textbook on neutron cross sections and evaluated nuclear data for safety design and safety evaluation of nuclear facilities by themselves.

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Reference

[1] Nuclear Safety Commission: "1991 Annual Report on Nuclear Safety in Japan" (1992).