Standards for Transport and Storage Components Established by The Atomic Energy Society of Japan and The Japan Society of Mechanical Engineers

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1. Introduction

Since June 1997 the standards/specifications and inspection/certification of various products in Japan have been reviewed by Ministries and Agencies, with the aim of reducing direct government intervention to a necessary minimum and creating a free and fair socio-economic system that is fully opened to the international community and based on the rules of self-responsibility and market principles. Reflecting this policy the administrative regulations which prescribe technical standards as specific requirements have been revised by degrees into performance prescriptions. Detailed provisions in ordinances and notices have been abolished gradually to utilize voluntary standards and rules.
In the nuclear energy field voluntary standards are being developed to make up statutory performance requirements by the Atomic Energy Society of Japan (AESJ) and the Japan Society of Mechanical Engineers (JSME) together with other organizations such as the Japan Electric Association, the Thermal and Nuclear Power Engineering Society. These voluntary standards and rules by these organizations have been established in order to maintain openness, transparency, fairness, professionalism and promptness and to promote development and globalization.

2. Standards Established by the AESJ

The Atomic Energy Society of Japan organized the Standard Committee in September 1999 to provide standards and guidelines for safety design and assessment of nuclear facilities. The Standard Committee constitutes three technical committees to plan, review, approve and maintain technical standards and guidelines as shown in Figure 1, covering a wide range of nuclear installations. Each technical committee can set up ad-hoc subcommittees to draft standards or a guidelines on specific subjects.
For the aspects related to the transport and/or storage of radioactive materials, the Subcommittee on Transport Packagings and the Subcommittee on Recycle Fuel Storage Facilities were formed in April 2000 and in June 2000 respectively, and have developed the following standards.

- For transport;
  - (1) Standard for Periodic Inspection and Maintenance of Shipping Casks for Spent Fuel, Fresh Mix-Oxide Fuel and High Level Radioactive Waste (December 2000)
  - (2) Standard for Safety Design and Inspection of Shipping Casks for Spent Fuel, Fresh Mix-Oxide Fuel and High Level Radioactive Waste (expected in December 2004)
- For transport and storage;
  - (3) Standard for Safety Design and Inspection of Metal Casks for Spent Fuel Interim Storage Facilities (June 2001. Revised January 2004)
  - (4) Standard for Safety Design and Inspection of Concrete Casks and Canister Transfer Machines for Spent Fuel Interim Storage Facilities (expected in March 2005)

2.1 Standard for Periodical Inspection and Maintenance of Transport Packagings

B(U), B(M) and fissile packaging shall be certified as an "approved packaging" by the competent authorities in order to be used to transport in Japan. The packaging approval can be extended proof that safety functions are being maintained, i.e. sound results in periodical inspections. The methods, criteria and intervals of these inspections

are stipulated in the safety analysis reports (SARs) which are subjected to design approval by the competent authority.
This standard prescribes procedures for establishing an inspection and maintenance scheme to be stipulated in the SARs, using the "Failure Mode and Effect Analysis (FMEA)" method. In an appendix of the standard this method is justified by a case study of inspection and maintenance records of spent fuel packagings used for years. This standard also shows how inspection items can be reduced when packagings are not in use for a long time. However, a full scope of inspection has been done annually under the current approvals.
Applications for revised design approval of NFT type packages adopted improved periodical inspection scheme based on this standard have been filed and the review by the authority is underway.

2.2 Standard for Safety Design and Inspection of Transport Packagings

This standard aims to serve as a "Cask Designer's Guide" for large B(U) or B(M) fissile packages which contain spent nuclear fuel assemblies, fresh Mix-Oxide fuel assemblies or high level vitrified waste canisters. It prescribes design methods and criteria of such packages to maintain safety functions - i.e. containment, heat removal, shielding and criticality prevention together with structural integrity of packaging and content - in order to prevent excessive public exposure to radiation even under the severe test conditions stipulated in the transport regulations. Inspection method and criteria for fabrication, pre-shipment and maintenance are also prescribed to ensure that the safety functions are kept within designed ranges.
Though requirements adopted in the standard are rather simple, essential and conventional, 65 mandatory and non-mandatory appendices consist with data for design and verification, sample analysis, interpretations, etc., help users to understand and utilize the standard.

2.3 Standard for Safety Design and Inspection of Metal Cask for Spent Fuel Storage Facilities

Japanese policy on the spent fuel generated at nuclear power station is to reprocess and utilize retrieved plutonium and uranium. Under the policy interim storage is important as a measure to add flexibility to the management of the nuclear fuel cycle. The future gap estimated between spent fuel generation and reprocessing capacity has increased the needs for interim storage facilities to store spent fuel as a retrievable energy source. The Law for the Regulations of Nuclear Source Material, Nuclear Fuel Material and Reactors was amended in June 1999, adding the Spent Fuel Storage Business, and electric power companies are now preparing to commission interim storage facilities away from reactors by 2010.
Under these circumstances the Subcommittee on Recycle Fuel Storage Facilities was called in July 2000 to establish standards and guidelines on safety design and safety assessment for the envisaged spent nuclear fuel interim storage facilities. The subcommittee considered that metal cask storage will be the first interim storage method to be employed in Japan, and established a standard on metal casks for spent fuel interim storage in June 2002, interacting with "The Technical Requirements for Spent Fuel Interim Storage Facilities with Metal Casks" set by the Agency for Natural Resources and Energy (ANRE) of the Ministry of Economy, Trade and Industry (METI).
In October 2002 the Nuclear Safety Committee (NSC) of Japan established "The Guidelines of Safety Review for Spent Nuclear Fuel Interim Storage Facilities using Metallic Dry Casks." While there were few discrepancies among the standard by the AESJ, the technical requirements of ANRE and the guidelines of NSC, the Subcommittee revised the original standard mainly to reflect above guidelines in January 2004.

The metal casks specified in the standard, whose typical concepts are illustrated in Figure 3, are to be used not only for storage at the spent fuel interim storage facility, but also used consistently for transport to and from the facility. Therefore, the standard provides the design requirements to maintain four safety functions, namely containment, heat removal, shielding and criticality prevention, which are defined as the "basic safety functions", and the structural integrity of cask itself and of spent fuel cladding during transport and storage. Inspection methods and criteria to ensure the basic safety functions and structural integrity over every stage of operations involving metal cask such as in fabrication, pre-shipment at nuclear power stations, receiving at storage facilities, during storage (in-service) and pre-shipment after storage are prescribed as well.
Prerequisite conditions to store spent fuel in a storage facility are as follows;

(1) Spent fuel assemblies stored shall be confirmed intact at nuclear power plants.
(2) Long term integrity of cask components and spent fuel during storage shall be demonstrated beforehand the pre-shipment inspection after storage.
(3) Metal casks shall be stored in a storage building.
(4) Spent fuel assemblies shall not repacked in the storage facility.

To prevent excessive public exposure to radiation and criticality of fissile material under credible conditions during storage and under the severe test conditions in the transport regulations the following design requirements are set in the standard.

(1) Cask cavities shall be dry and filled with inert gas (helium), and kept under atmospheric pressure except under the accident conditions prescribed in the transport regulations.
(2) Doubled lid system with pressurized inter-lid space shall be provided and inter-lid pressure shall be monitored continuously during storage.
(3) During transport secondary (outer) lid or additional lid shall maintain confinement function to comply with the transport regulations.
(4) Metallic gaskets used for storage shall maintain the design leak rate for storage under routine condition of transport from nuclear power stations to storage facilities. When metallic gaskets used during storage are to be used as a confinement boundary for transport after storage, design leak rate for transport shall be maintained including the accident conditions stipulated in the transport regulations.
(5) By passive heat removal the temperatures of cask components related to the safety and of spent fuel cladding shall be kept below the limits set to maintain integrity. Maximum allowable fuel cladding temperature, which shall be determined to limit creep strain and to avoid hydride crystallization effect during storage, shall not be exceeded before and during storage including the cavity dry up process at nuclear power station.
(6) Representative temperature of the surface of casks shall be monitored periodically during storage.
(7) Maximum credible leakage of radioactive material from spent fuel cladding shall be considered in the design of confinement and heat removal.
(8) Shielding performance of the cask shall meet the transport regulations.
(9) Subcriticality shall be kept under all credible conditions including spent fuel loading/ unloading operations.
(10) Structural design of cask components shall be in accordance with the Rules on Transport/Storage Packagings for Spent Nuclear Fuel established by the JSME.
(11) Safety functions shall be kept under the design limit earthquake defined by the seismic design guidelines.

In order to comply with above requirements demonstration tests and research to collect data on the long term integrity of spent fuel cladding, metallic gasket performance in transportation after storage, etc. are underway. When these data are collected, they will be reflected to the standard.

2.4 Standard for Safety Design and Inspection of Concrete Casks for Spent Fuel Storage Facilities

As the concrete cask storage system was considered as another possible method of spent fuel interim storage, the Subcommittee on Recycle Fuel Storage Facilities started drafting the standard in May 2002. The standard will be expected to be approved by the Standard Committee for public review in October this year.
Compared with the metal cask storage system where metal casks are the only major components for transport and storage, the concrete cask storage system involves several components important to safety with rather complicated operational sequences described in Figure 4. Concrete casks are defined as concrete overpack containing canisters. Spent fuel assemblies are canned in the canisters at a nuclear power station. Canisters are transported in canister transport casks to an interim storage facility, then transferred into concrete overpacks from the canister transport casks by canister transfer machine. After storage canisters will be loaded into canister transport casks again to be transported outside the storage facility to unload spent fuel assemblies.

In this standard essential components employed in this system are considered as concrete casks, canister transfer machines and canister transport casks. Among these components canister is subjected to transport and storage, and requirements are the same as for metal casks except for the following;

(1) Canister cavities can be pressurized over atmospheric pressure to improve heat transfer inside.
(2) Lid(s) of canisters shall be closed by welding after the spent fuel loading. Redundant welding joint for the lid system shall be provided to double the barrier against leakage through the joints.
(3) No monitoring on confinement of canister is required.
(4) Confinement failure by stress corrosion cracking (SCC) shall be prevented by anti-corrosion designs such as material selection, stress relief after welding and measures to limit salt particles in storage environments.
(5) Heat removal and shielding performance of the canisters shall be designed to integrate with concrete overpacks, canister transfer machines and the canister transport casks. Seismic requirements shall be fulfilled in conjunction with concrete overpacks and canister transfer machines.

Requirements for the concrete overpacks and the canister transfer machines are prescribed from the viewpoint of heat removal, shielding and support structure for canisters. No requirement is set for the canister transport casks,

since the Standards for Transport Packagings can be applied when considering canisters as contents of the packages. Structural design of these components shall be in accordance with the Rules on Concrete Casks, Canister Transfer Machines and Canister Transport Casks established by the JSME.
The critical issue regarding the utilization of this standard is to collect further demonstration data to absolutely prevent stress corrosion cracking of the canister.

3. Standards Established by the JSME

The Japan Society of Mechanical Engineers created the Power Generation Code Committee in October 1997 to establish voluntary structural design and construction rules for power generation facilities aiming to replace statutory technical standards enforced as ministry notices. Since then a full set of Codes for Thermal Power Generation Facilities and most of the Codes for Nuclear Power Generation Facilities have been published. The structures and provisions of these codes are very similar to those of the Boiler and Pressure Vessel Code (B&PV Code) of the American Society of Mechanical Engineers (ASME). Organization of the Committee is shown in Figure 2.
For transport and storage of radioactive material the Subgroup on Spent Fuel Storage Facilities was set in April 1999 within the Subcommittee on Nuclear Power, and the following rules have been established as a part of the Codes for Construction of Spent Nuclear Fuel Storage Facilities;

(1) Rules on Transport/Storage Packagings for Spent Nuclear Fuel (August 2001)
(2) Rules on Concrete Casks, Canister Transfer Machines and Canister Transport Casks (March 2004)

3.1 Structural Design and Construction Rules on Transport/Storage Packagings

The Rules on Transport/Storage Packagings consist of requirements for materials, structural design, construction and inspection of metal cask components. Three essential components of metal casks, which are containment vessels, baskets and trunnions, are covered.
Provisions in the rules are prescribed based on the Rules on Design and Construction for Nuclear Power Plants and Rules on Welding for Nuclear Power Plants of the JSME Codes for Nuclear Power Generation Facilities with some modifications in consideration of the characteristics of Transport/Storage Packagings. As summarised in Table 1, rules for Class 1 Vessel of the JSME Codes for Nuclear Power Generation Facilities are adopted as the basis of provisions for Containment Vessels in order to appropriately evaluate all conceivable loading conditions, i.e. to employ the 'design by analysis' method, and to achieve the possible highest quality. Due to the similarity of function to support fuel assemblies rules on Core Support Structures are taken for Baskets. From the view point of supporting the highest quality components applicable provisions form rules on Class 1 Component Support Structure are set for Trunnions considering their shape, loading type and required functions.
For the design of the components, allowable stress limits are given for each design condition, where the design conditions are ranked into five levels as shown in Table 2.

Table 1. Basis for Provisions of the Rules on Transport/Storage Packagings

Components	Basis for Provisions	
	JSME Design & Construction Code	ASME B&PV Code
Containment Vessel	Class 1 Vessel	Section III, Subsection NB or Subsection WB
Basket	Core Support Structure	Section III, Subsection NG
Trunnions	Class 1 Component Support Structure	Section III, Subsection NF

Table 2. Design Conditions defined in the Rules on Transport/Storage Packagings

Conditions defined in the rules on Transport/Storage Packagings	Concept		Equivalent conditions in the JSME Design & Construction Code or the ASME B&PV Code
	Storage	Transport	
Design Condition I	Normal Operation	Normal condition	Level A Service Condition
Design Condition II	Off-normal Operation	Routine condition	Level B Service Condition
Design Condition III	Emergency State	-----	Level C Service Condition
Design Condition IV	Hypothetical Accident	Accident condition	Level D Service Condition
Test Condition	Pressure Test	Pressure Test	Test Condition

Typical differences from the Rules for Nuclear Power Plant Components are as follows;

(1) Stress in seal region of the containment vessel shall not exceed yield strength of the material even under Design Condition IV, since the containment function shall be maintained under all conceivable conditions.

(2) Requirements for the basket and trunnions are simplified with consideration to their shape and loads introduced. For example, fatigue analysis on the basket is not required, since no cyclic load is expected to work on it.
(3) Trunnions can be designed only for Design Conditions I and II, since no function is required under the Design Conditions III and IV. Special stress limits are given to trunnions with consistency to conventional assessment methods for transport packages.
(4) Ductile cast iron (JIS FCD300LT) can be used as a material for containment vessel. Special fracture toughness requirements are given for ductile cast iron. Massive forged steel (ASME SA-350 Gr.LF5) can also be used and fracture toughness requirements are specified as conventional.
(5) Stress limits for earthquakes during storage are given in accordance with the guidelines from the Architect Institute of Japan (AIJ).

3.2 Structural Design and Construction Rules on Components for the Concrete Cask Storage System

Immediately after the completion of the Rules for Transport/Storage Packagings (Metal Cask), the subcommittee started drafting of Rules on Components for the Concrete Cask Storage System in March 2001. Thanks to the collaborations among experts regarding materials, mechanical engineering, architect engineering, civil engineering and so on integrated rules incorporating with steel and concrete structures was published March 2004.
Basis for provisions in the rules come from the Rules on Transport/Storage Packagings, Design and Construction of Nuclear Power Plants of the JSME and Guidelines etc. of the AIJ as shown in Table 3.
While rules on steel structures are more or less the same to the ones on the transport/storage of packagings, special consideration is given to design, construction and inspection on the lid welding joints of the canister. Rules on concrete structure are rather conventional, but additional requirements for the high temperature parts are provided.

Table 3. Basis for Provisions of the Rules on Components of Concrete Cask Storage System

Components of Concrete Cask Storage System		Basis for Provisions
Canister	Containment Vessel	Containment Vessel of Transport/Storage Packagings
	Basket	Basket of Transport/Storage Packagings
	Canister Lifting Lug	Trunnions of Transport/Storage Packagings
Concrete Overpack	Structural Part (Metal Structure)	Class 1 Component Support Structure of JSME Design & Construction Code
	Concrete Structure	Design and Construction Specifications, Guidelines from the Architect Society of Japan
Canister Transfer Machine	Structural Part	Class 1 Component Support Structure of JSME Design & Construction Code
	Driving Mechanisms	Safety Provisions from Crane Structural Code
Canister Transport Cask	Containment Vessel	Containment Vessel of Transport/Storage Packagings
	Trunnions	Trunnions of Transport/Storage Packagings

4. Conclusions

Recent years numerous voluntary standards and rules have been established for the thermal and nuclear power generation facilities and nuclear fuel cycle facilities in Japan corresponding to the policy to minimise direct governmental intervention.
Among them the standards and rules for the transport and storage of radioactive materials established by the Atomic Energy Society of Japan and the Japan Society of Mechanical Engineers are expected to assist the licensing of components for fuel cycle transportation and spent fuel interim storage facilities, which will be in operation by the year of 2010 in Japan. These standards and rules will be a licensing standard when endorsed by the competent authority, or will be the basis for licensing documents.

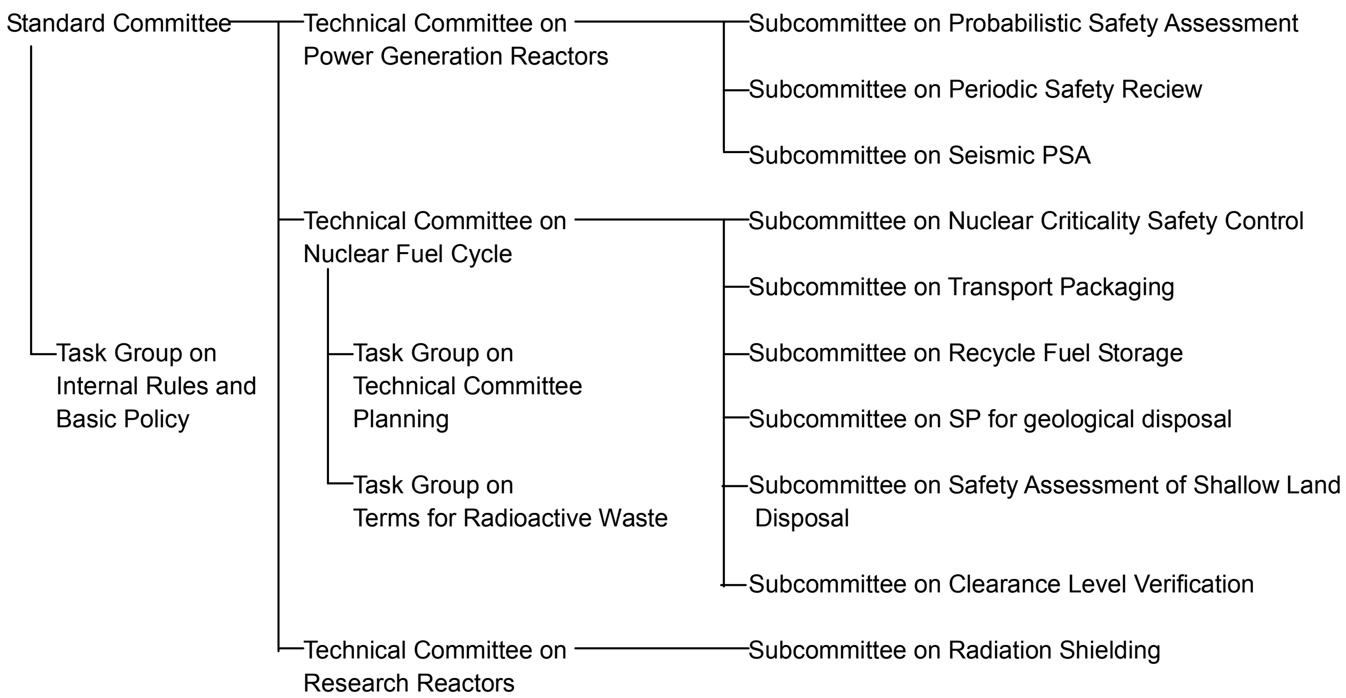

Fig. 1. Organization of the AESJ Standard Committee

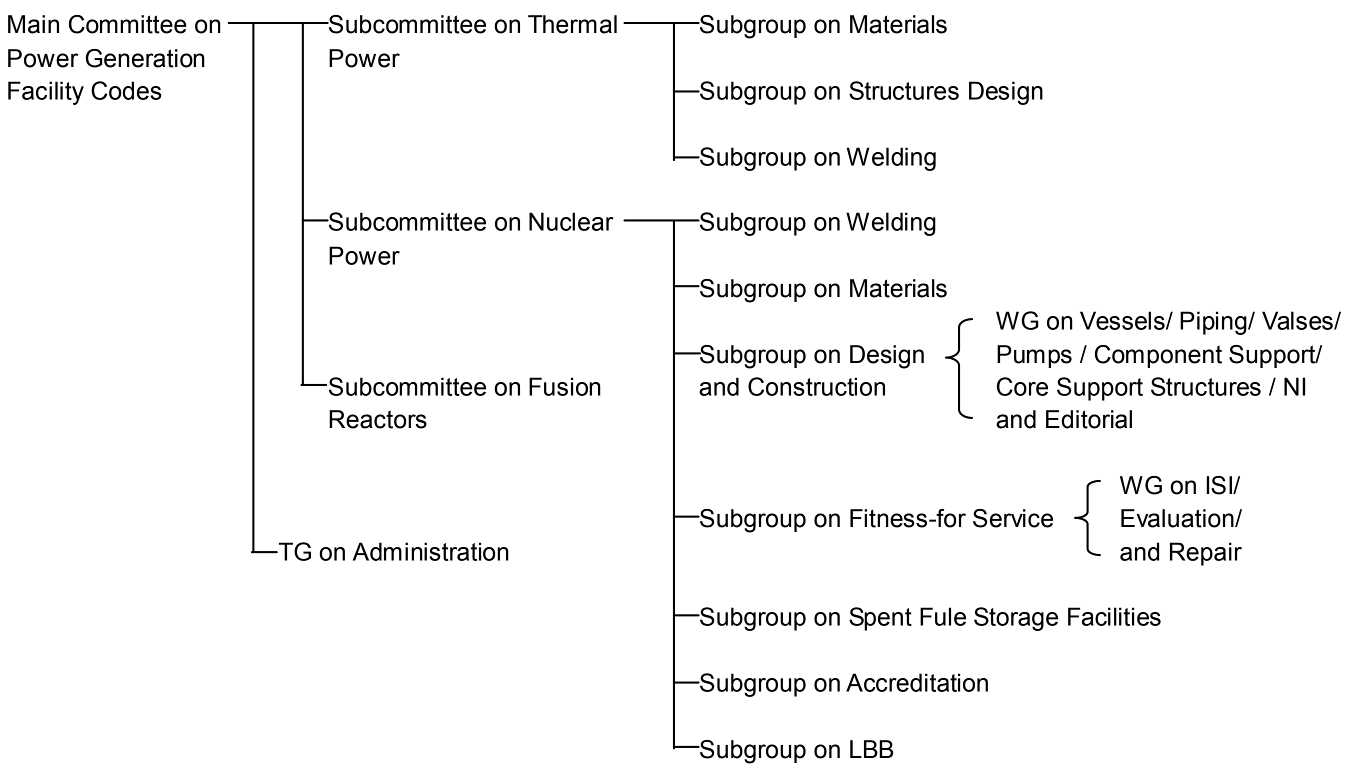

Fig. 2. Organization of the JSME Committee on Power Generation Facility Codes

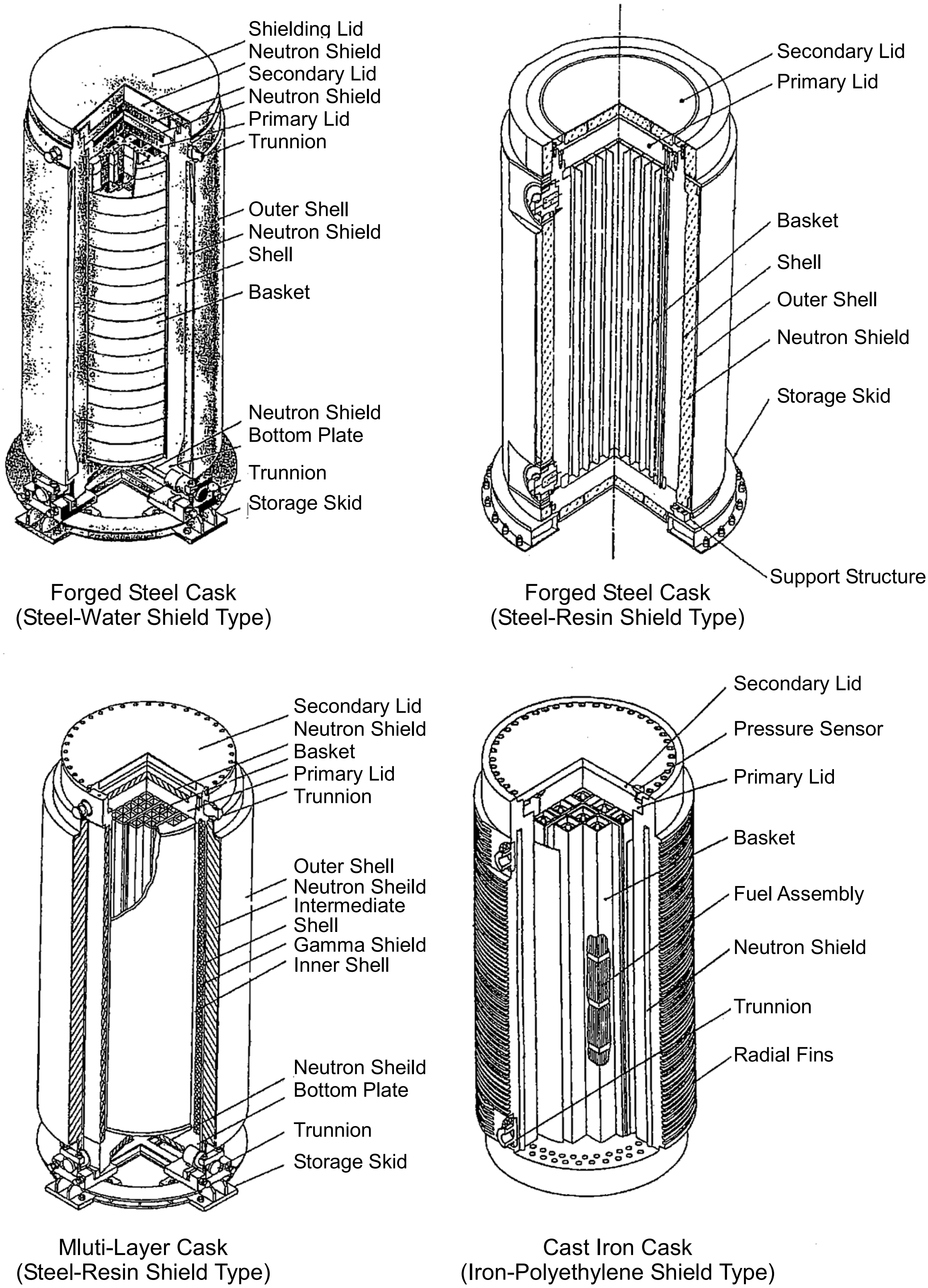

Fig. 3. Design Concepts of Metal Casks (Transport/Storage Packagings)

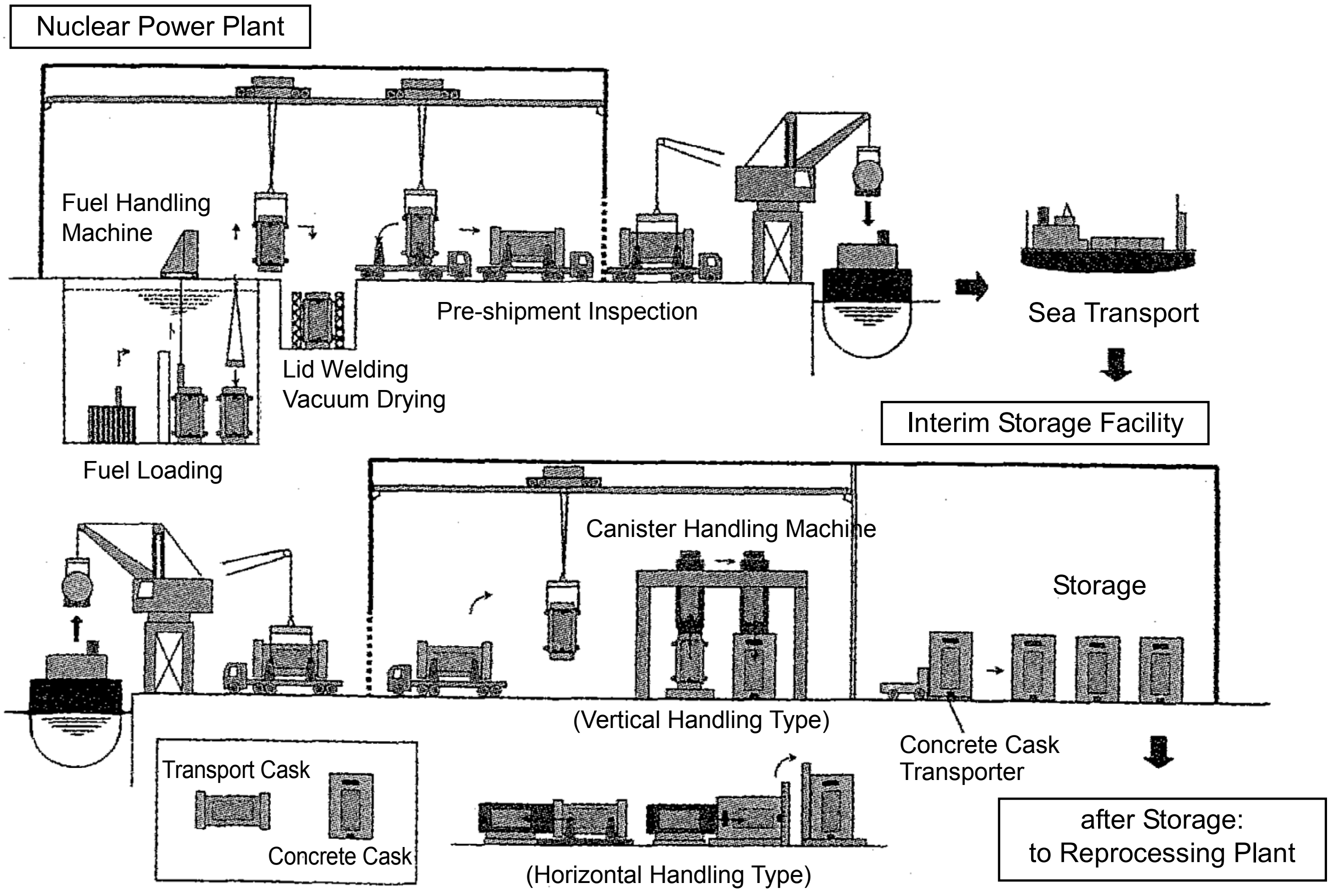

Fig. 4. Operational Sequences involved in the Concrete Cask Storage System