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Subject: Submittal of Technical Report [4S Response to 73 FR 60612,"Policy Statement on the Regulations of Advanced Reactors" and SECY-10-0034,"Potential Policy, Licensing, and Technical Issues for Small Modular Nuclear Reactor Designs"]

Enclosed is a copy of the non-proprietary Technical Report [4S Response to 73 FR 60612,"Policy Statement on the Regulations of Advanced Reactors" and SECY-10-0034,"Potential Policy, Licensing, and Technical Issues for Small Modular Nuclear Reactor Designs"] for the 4S (Super-Safe, Small and Simple) reactor plant that is currently the subject of a pre-application review among NRC, Toshiba, and its 4S affiliates including Japan's Central Research Institute for Electric Power Industry (CRIEPI).

The pre-application review for the 4S reactor commenced in the fourth quarter of 2007. Pre-application review meetings were held among NRC, Toshiba and the 4S affiliates in October 2007, and February, May and August 2008.

The technical report pertaining to the Principal Design Criteria was scheduled to be submitted to NRC in former half of FY2011 as stated in TOS-CR-4S-2010-0001 "Toshiba Corporation (Toshiba) Response for the 4S Reactor (4S) to Regulatory Issue Summary (RIS) 2010-03". However, Toshiba has decided that we will prepare the report in accordance with the ANSI/ANS-54.1 "Nuclear Safety Criteria and Design Process for Sodium-Cooled Reactor Nuclear Power Plants" currently under development and will submit after the issuance of the ANSI/ANS-54.1 standard. In stead, Toshiba provides this report in order to have NRC's feedback as early as possible since we think the resolution of those issues are more important. This report presents Toshiba's response to the issues raised in SECY-10-0034 "Potential Policy, Licensing, and Key Technical Issues for Small Modular Nuclear Reactor Designs" and 73 FR 60612 "Policy Statements on the Regulation of Advanced Reactors".

Additional technical reports pertaining to the 4S design will be submitted as the pre-application review progresses. If you have any questions regarding this document, please contact Mr. Tony Grenci of Westinghouse at (623) 271-9992, or grencit@westinghouse.com.

Very truly yours,

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4S Response to

73 FR 60612, "Policy Statement on the Regulation of Advanced Reactors"

and

SECY-10-0034, "Potential Policy, Licensing, and Key Technical Issues for Small Modular Nuclear Reactor Designs"

October 2010

TOSHIBA CORPORATION

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LIST OF ACRONYMS AND ABBREVIATIONS

4S	Super-Safe, Small and Simple
AC	Air Cooler
ANS	American Nuclear Society
AOO	Anticipated Operational Occurrence
ASME	American Society of Mechanical Engineers
ATWS	Anticipated Transient without Scram
BOP	Balance of Plant
CDF	Core Damage Frequency
CFD	Computational Fluid Dynamics
CFR	Code of Federal Regulations
COL	Combined License
CRBR	Clinch River Breeder Reactor
DA	Design Approval
DBA	Design Basis Accident
DID	Defense in Depth
DOE	Department of Energy
DWSG	Double-Wall Steam Generator
EBR-II	Experimental Breeder Reactor-II
EM	Electromagnetic
EPZ	Emergency Planning Zone
FCA	Fast Critical Assembly
FEMA	Federal Emergency Management Agency
FFTF	Fast Flux Test Facility
FMEA	Failure Mode and Effect Analysis
FP	Fission Product
FR	Federal Resister
GDC	General Design Criteria
HTGR	High-Temperature Gas-Cooled Reactor
HVAC	Heating, Ventilation and Air Conditioning
IHTS	Intermediate Heat Transport System
IHX	Intermediate Heat EXchanger
IRACS	Intermediate Reactor Auxiliary Cooling System
IRIS	International Reactor Innovative and Secure
LERF	Large, Early Release Frequency
LMR	Liquid Metal Reactor
LOF	Loss of Flow
LWR	Light Water Reactor
MC&A	Material Control and Accounting
MHTGR	Modular High-Temperature Gas-Cooled Reactor
MLD	Master Logic Diagram
NEI	Nuclear Energy Institute
NGNP	Next Generation Nuclear Plant

LIST OF ACRONYMS AND ABBREVIATIONS (cont.)

NRC	Nuclear Regulatory Commission
PHTS	Primary Heat Transport System
PIRT	Phenomena Identification and Ranking Table
PRA	Probabilistic Risk Assessment
PRISM	Power Reactor Innovative Small Module
PWR	Pressurized Water Reactor
QA	Quality Assurance
QC	Quality Control
R&D	Research and Development
RHRS	Residual Heat Removal System
ROP	Reactor Oversight Process
RVACS	Reactor Vessel Auxiliary Cooling System
SA	Severe Accident
SECY	Commission papers
SFR	Sodium-Cooled Fast Reactor
SG	Steam Generator
SMR	Small Modular Reactor
SSC	Structure, System, and Component
US	United States of America
WSS	Water Steam System

1 INTRODUCTION

During the fourth pre-application meeting on the Super-Safe, Small and Simple (4S) liquid metal fast reactor[1], Toshiba described to the United States Nuclear Regulatory Commission (NRC) staff how the 4S reactor meets the NRC expectations specified in the "Regulations of Advanced Reactors, Draft Statement of Policy," (73 FR 26349)[2]. Subsequently Toshiba submitted comments on the draft statement of policy, and the NRC issued the final "Policy Statement on the Regulations of Advanced Reactors," (73 FR 60612)[3]. This report describes how the 4S meets the NRC expectations specified in that final policy statement.

The report also responds to the NRC staff issues raised in SECY-10-0034[4], "Potential Policy, Licensing, and Key Technical Issues for Small Modular Nuclear Reactor Designs." The staff identified fifteen issues that need to be resolved.

Section 2 describes the purpose and scope of this report. Section 3 presents the response to the regulatory issues raised by the NRC staff in Reference 4 (Section 3.1) and the 4S design and design process features that satisfies the NRC expectations expressed in References 3 (Section 3.2). Section 4 summarizes the main conclusions of the report.

The 4S responses to the SECY-10-0034 issues classified as "high importance" that need to be resolved in 2010-2011 are summarized below. Section 3.1 contains more detailed responses and responses to other issues in SECY-10-0034.

1. *Implementation of the Defense-in-Depth (DID) Philosophy (SECY-10-0034 section 3.1)*: The 4S uses the defense-in-depth philosophy defined in the NRC glossary of terms[5]. The reactor has three traditional physical barriers of fuel cladding, reactor coolant boundary, and containment similar to light water reactors (LWRs) and sodium-cooled fast reactors (SFRs) reviewed previously by the NRC [Clinch River Breeder Reactor (CRBR) and Power Reactor Innovative Small Module (PRISM)]. The design satisfies the fourth attribute of the Policy Statement on the Regulation of Advanced Reactors[3] aiming to "minimizing the potential for severe accidents and their consequences, with emphasis on minimizing the potential for accidents over minimizing the consequences of such accidents." Sections 3.1 and 3.2 of this report describe the design features that demonstrate the 4S prevention and mitigation capabilities and the design robustness to external challenges including security threats.

2. *Appropriate Source Term, Dose Calculations, and Siting (SECY-10-0034 section 3.3)*: This issue covers site-specific issues and multi-module source terms. The 4S design approval (DA) application will be based on a single module with generic site parameters that bound a number of sites in the US. Therefore, this issue will be discussed at the combined license (COL) application stage if necessary. As stated under issue number 1 above, the 4S has a goal of minimizing the risk with more emphasis on accident prevention than mitigation which is consistent with the NRC Policy Statement on the Regulations of Advanced Reactors[3]. Preliminary 4S PRA shows no credible accident that will lead to core

damage. Consequently, the 4S will use a bounding radioactive release from the fuel to the primary sodium, with conservative assumptions used for the transport and release from the reactor vessel and containment as necessary to accommodate residual uncertainties.

3. *Core Composition and Source Term Issues (SECY-10-0034 section 3.4)*: The core composition and its relation to irradiated fuel shipping and offsite storage will be discussed at the COL application stage.

4. *Accident Selection for Small Modular Reactors (SMRs) (SECY-10-0034 section 3.4)*: The 4S uses event categories similar to those of the Standard Review Plan (SRP) Chapter 15 [Anticipated Operational Occurrence (AOO), Design Basis Accident (DBA), and Anticipated Transient without Scram (ATWS)]. Failure Modes and Effects Analysis (FMEA) and a Master Logic Diagram (MLD) were used to identify critical failures especially those related to innovative designs and accident sequences that lead to AOO, DBA, and ATWS. Historic failure rate data, and the evaluation of events reported in licensing documents for the PRISM and CRBR were used to assign events to event categories.

5. *Redundancy of the Passive Residual Heat Removal System (SECY-10-0034 section 3.4)*: The 4S has two redundant and diverse residual heat removal systems (RHRSs). One of the systems (reactor vessel auxiliary cooling system: RVACS) is continuously running with its performance monitored for any degradation. The other system (intermediate reactor auxiliary cooling system: IRACS) is initiated when needed using a redundant, fail-safe dampers to allow natural circulation of atmospheric air. The two systems are safety-related.

6. *Classification of Structure, System, and Component (SSCs) (SECY-10-0034 section 3.4)*: The 4S SSCs are classified by deterministic judgment complemented by 4S-specific risk insights available at the DA application stage.

7. *Containment Functional Capability (SECY-10-0034 section 3.4)*: The 4S has three barriers to retain fission products (the fuel cladding, the reactor coolant boundary, and containment) similar to the LWRs. The containment will be installed below grade, which reduces its vulnerability to terrorist attack and aircraft impact.

8. *Security and Safeguard Requirements (SECY-10-0034 section 4.5)*: The 4S design process has integrated security with safety since the beginning of the project. This is reflected in key provisions in the design such as below grade installation, no refueling throughout the 30 year life of the reactor, sealed reactor vessel, and no reliance of the

safety systems, including the shutdown heat removal, on balance-of-plant equipment or offsite power.

2 PURPOSE AND SCOPE

2.1 Purpose

The purpose of this report is threefold:

1. To update the information presented to the NRC staff during the 4S fourth pre-application meeting to be consistent with the final "Policy Statement on the Regulation of Advanced Reactors,"[3]

2. To respond to the issues raised by the NRC staff in SECY-10-0034[4], and

3. To obtain feedback from the NRC staff on the presented material either in writing or in a meeting at the staff's convenience. Such feedback will be greatly beneficial for the 4S project to complete its DA application.

2.2 Scope

This report presents Toshiba's response to the issues raised in the NRC policy statement of Reference 3 and SECY-10-0034[4]. The report identifies the 4S design innovative and passive features that satisfy the broad range of goals and attributes expected by the NRC from advanced reactors and SMRs. The report discusses the implementation of the DID in the 4S design, the use of 4S-specific risk insights available at the DA application stage to complement deterministic engineering judgment, and the integration of safety and security in the 4S design process from the early stages of the design. More detailed information on the 4S design, safety analysis, and regulatory compliance can be found in References 6, 7, 8, 9, 10, 11, 12, and 13.

3 4S RESPONSE TO THE REGULATORY ISSUES

3.1 Response to the Issues in SECY-10-0034 "Potential Policy, Licensing, and Key Technical Issues for Small Modular Nuclear Reactor Designs"

Responses to the issues classified as high importance by the NRC in SECY-10-0034[4], "Potential policy, licensing, and key technical issues for small modular nuclear reactor designs" are described in Table 3.1. And the responses to the issues classified as medium and low importance are described as follows. Paragraphs in *italic* type are excerpts from the SECY-10-0034.

- *License Structure for Multi-Module Facilities and Annual Fee for Multi-Module Facilities (SECY-10-0034 section 2.2 and 5.1)*

  These issues are not applicable to 4S, because 4S is not designed for modular use.

- *Manufacturing License Requirements for Future Reactors (SECY-10-0032 section 2.3)*

  Toshiba does not plan to apply for manufacturing license of 4S.

- *Operational Programs for Small or Multi-Module Facilities (SECY-10-0034 section 4.2)*

  The information pertinent to this issue will be provided at the time of the COL application.

- *Insurance and Liability for SMRs (SECY-10-0034 section 5.2)*

  Toshiba expects resolution of the issues related to insurance and liability for SMR by the time of the COL application of 4S.

- *Decommissioning Funding for SMRs (SECY-10-0034 section 5.3)*

  The information pertinent to this issue will be provided by the time of the COL application stage.

3.2 Conformance and Design Response to 73 FR 60612, "Policy Statement on the Regulation of Advanced Reactors"

The relationship between design of the 4S SSCs and each attributes is shown in Table 3.2.

Fourteen attributes are defined in the policy statement of advanced reactors[3]. The applicability of each attribute to 4S and the 4S design response to the applicable items are addressed as follows. Paragraphs in *italic* type are excerpts from the policy statement.

(1) Attribute 1

Highly reliable and less complex shutdown and decay heat removal systems. The use of inherent or passive means to accomplish this objective is encouraged (negative temperature coefficient, natural circulation, etc.).

In response to this attribute, 4S is designed to satisfy the following conditions.

- The temperature reactivity coefficient of the core is negative and thus reduces the need for rapid reactor shutdown.

- Redundant and diverse shutdown systems (reflector and shutdown rod) are provided. During normal operating conditions, reactor core power is controlled by a movable reflector. The reflector drive consists of a combination of fine and fast adjustment mechanisms. To scram the reactor, the clutch at the fast adjustment mechanism is released, and the reflector lowers via gravity causing the reactor to shut down. For burnup swing compensation, the reflector is driven by fine control system and continuously moving. The load of the reflector is measured continuously, so any degradation in their performance, such as the abnormal load changes due to increased friction, will be detected and corrective action taken before an event requiring its use occurs.

- Two redundant and diverse RHRSs, the RVACS and IRACS, are provided as shown in Fig. 3.1. Each system can independently remove the residual heat in the core. The IRACS removes decay heat by using an air cooler in the intermediate heat transport system (IHTS). The RVACS removes the decay heat alone with natural convection of air outside the reactor guard vessel and does not require electric power. The RVACS removes the heat continuously even during normal operation. As a result, any degradation in the RVACS performance will be identified and corrective action taken before an event requiring its use occurs.

(2) Attribute 2

Longer time constants and sufficient instrumentation to allow for more diagnosis and management before reaching safety systems challenge and/or exposure of vital equipment to adverse conditions.

In response to this attribute, 4S is designed to satisfy the following conditions.

- Longer time constants in the 4S result from two factors: the negative reactivity feedback stated at the first attribute and the large thermal inertia of the primary sodium relative to the small power density of the core. These factors reduce the rate of temperature increase in case of accidental reactivity increase. This allows more time for diagnosis and corrective action to bring the reactor back to normal operation (Fig. 3.2).

- The instrumentation system is reliable and extensive. 4S is operated conservatively relative to any design limits.

- Monitoring of structure including sodium and mitigation of steam and/or sodium leakage from steam generator precludes sodium fires and sodium/water reactions.

(3) Attribute 3

Simplified safety systems that, where possible, reduce required operator actions, equipment subjected to severe environmental conditions, and components needed for maintaining safe shutdown conditions. Such simplified systems should facilitate operator comprehension, reliable system function, and more straightforward engineering analysis.

In response to this attribute, 4S is designed to satisfy the following conditions.

- The simplified safety systems such as the shutdown systems (shutdown rod and reflector) and the RHRSs are employed and reduce the operator action.

  - Fail-safe reactor shutdown systems

    - ➢ Shutdown rod drive system: As shown in Fig. 3.3, the shutdown rod is positioned on standby and connected with a guide tube. A latch is connecting the guide tube and shutdown rod when the current in the electromagnet is turned on. In case of electric power loss, the latch is released and the shutdown rod is separated as the current passing through the electromagnet is removed. Finally, the shutdown rod lowers into the core via gravity, which results in reactor shutdown.

    - ➢ Reflector drive system: As shown in Fig. 3.4, the reflector drive system transmits motor drive force to the power cylinder using an electromagnetic clutch, and the reflector is maintained in the prescribed position. When electric power is lost, the electromagnetic clutch of the reflector drive unit is separated. As a result, the reflector lowers via gravity and causes the reactor to shut down.

  - Fail-safe RHRSs

    - ➢ Heat removal via IRACS is initiated automatically by opening the fail-safe air cooler damper when a scram signal is transmitted. When electric power is lost, the damper is opened.

    - ➢ RVACS has no active components and continuously removes heat from the reactor vessel not only at abnormal operation, but also under normal operation.

Hence, this system ensures the operation at abnormal event even without fail safe system.

- Severe environmental conditions are inherently less likely due to the 4S design (e.g., minimal essential equipment in containment, sealed reactor vessel accompanied by the non-refueling core).

- The main safety components within the containment system are the reflector drive mechanisms and the shutdown rod drive mechanisms. The containment is inerted during power operation as a preventive measure against sodium fire. Even if a sodium leak occurs in the containment vessel, the reactor shutdown mechanisms will be capable of shutting down the reactor.

- Human factors considerations have been incorporated in the control room design to facilitate operator comprehension.

(4) Attribute 4

Designs that minimize the potential for severe accidents and their consequences by providing sufficient inherent safety, reliability, redundancy, diversity, and independence in safety systems, with an emphasis on minimizing the potential for accidents over minimizing the consequences of such accidents.

In response to this attribute, 4S is designed to satisfy the following conditions.

Initiators of severe accidents (SAs), which were previously identified as shown in Table 3.3, are prevented by passive safety and evolutionary design elements such as:

- Risk reduction by passive safety

  - Metallic fuel/sodium coolant compatibility
    (No accident propagation after clad failure)
  - Negative reactivity temperature coefficient
  - Natural circulation
  - Sodium high fission products retention capabilities; affinity to halides, and scrubbing of non-gaseous fission products
  - Low enthalpy of metallic fuel

- Risk reduction by evolutionary design

  - No refueling core
    (No intrusion of impurity due to refueling)
  - Seismic isolators
  - Electromagnetic (EM) pumps
    (Elimination of intruding lubricant due to no rotating parts)

- Redundant flow path of inlet assembly modules
  (Multi orifice hole at the inlet of the assemblies prevents the flow blockage.)
- Redundant and diverse passive RHRSs
- Double-wall steam generator (DWSG) tubes with leak detection (Figs. 3.5)
- Minimal containment penetrations
  (Minimal essential components in containment) (Attribute 3)
- Backup core support structure (Fig. 3.6)

4S unique potential initiator of SAs is prevented by redundancy of passive components such as:

- Multiple cavity cans (Fig. 3.7): Cavity cans are installed above the reflector region. They enhance the increase in neutron leakage from the core relative to the surrounding sodium coolant. Each segment of reflector assembly contains six cavity cans and restrict the insertion of positive reactivity by sodium intrusion as a result of a single can failure.

(5) Attribute 5

Designs that provide reliable equipment in the balance of plant (BOP) (or safety-system independence from BOP) to reduce the number of challenges to safety systems.

The 4S is designed based on the principle of safety system independence from the BOP. In particular, no cooling water system or BOP heat sink is used for the 4S as indicated below.

- IRACS and RVACS use atmospheric heat sink.
- Use of immersed-type EM pump for primary cooling system; no BOP cooling (Fig. 3.8).
- Use of heat-resistant EM pump for intermediate cooling system; no BOP cooling (Fig. 3.9).
- Heating, ventilation and air conditioning (HVAC) system does not rely on cooling water; uses atmospheric heat sink.

(6) Attribute 6

Designs that provide easily maintainable equipment and components.

One of the objectives of the 4S reactor design is to minimize the maintenance needs and outages. This is accomplished by the reduced maintenance of the following key components.

- No refueling

A fuel handling machine is required to be brought to the plant site only at initial fuel loading and at unloading after 30 years operation. Therefore, the maintenance of the fuel handling equipment during 30-year plant life is not required.

- Minimal active components in the reactor system
  - EM pumps have no moving parts
  - No rotating plug
- Minimal electrical and electronic components
- Reduced maintenance of primary components
  - Integrated EM pump and intermediate heat exchanger (IHX) can be removed as a unit for repairs if necessary (Fig.3.10).
  - No rotating parts, low corrosive environment

(7) Attribute 7

Designs that reduce potential radiation exposures to plant personnel.

In response to this attribute, 4S is designed to satisfy the following conditions.

- The possibility of exposure during maintenance, inspection, and repair is minimized by the following features:
  - No refueling
    (The radiation exposure due to fuel handling is reduced.)
  - Small radioactivity inventory
    (Small power reactor accumulates small radioactivity inventory.)
  - Minimally activated intermediate-loop sodium
  - No routine maintenance required in reactor silo
    (No access to reactor silo reduces the exposure comparing to LWR.)
  - Remote in-service inspection
  - Area radiation monitoring

(8) Attribute 8

Designs that incorporate the defense-in-depth philosophy by maintaining multiple barriers against radiation release, and by reducing the potential for, and consequences of, severe accidents.

In response to this attribute, 4S is designed to satisfy the following conditions:

- Multiple physical barriers are provided:
  - Fuel cladding
  - Primary coolant boundary
  - Containment boundary

- Functional barriers are provided for the following cases:
  - Prevention

    See response to Attribute 4.

  - Mitigation

    For mitigation of the radiological consequences of significant external releases of radiological material, examples of specific design features are identified with Attribute 4.

(9) Attribute 9

Design features that can be proven by citation of existing technology, or that can be satisfactorily established by commitment to a suitable technology development program.

In response to this attribute, 4S is designed to satisfy the following conditions:

- Existing technology has been used when available.
- Applicable tests have been performed to further develop the necessary technology.
- The worldwide liquid-metal reactor (LMR) technology base has been incorporated into the 4S reference base.
- Important knowledge gaps will be addressed by a suitable technology development program based on the 4S Phenomena Identification and Ranking Table (PIRT)[10].

(10) Attribute 10

Designs that include considerations for safety and security requirements together in the design process such that security issues (e.g., newly identified threats of terrorist attacks) can be effectively resolved through facility design and engineered security features, and formulation of mitigation measures, with reduced reliance on human actions.

In response to this attribute, 4S is designed to satisfy the following conditions:

- In order to mitigate the threats of terrorist attacks, the following design features are adopted:
  - Below-grade siting (Fig. 3-11)
  - A remote shutdown system which can remotely shut down the reactor is provided outside the control room
  - Passive safety systems
  - Security systems that comply with U.S. regulatory requirements
- The theft of nuclear fuel is prevented by:
  - Sealed reactor vessel
  - No fuel storage onsite (No refueling)
  - No fuel handling machine is kept onsite; the fuel handling system is transported to site when necessary.

(11) Attribute 11

Designs with features to prevent a simultaneous loss of containment integrity (including situations where the containment is by-passed), and the ability to maintain core cooling as a result of an aircraft impact, or identification of system designs that would provide inherent delay in radiological releases (if prevention of release is not possible).

In response to this attribute, 4S is designed to satisfy the following conditions:

- Below-grade installation of the reactor building mitigates (or eliminates) the effect of an aircraft impact.
- Heat removal after an aircraft crash is maintained using natural circulation of RVACS even with 50% of the flow path for RVACS is blocked without consideration of the effect of the stacks (Fig. 3.12 and Fig. 3.13). Fig. 3.13 shows the reactor outlet temperature when 50% of the flow path for RVACS is blocked.

(12) Attribute 12

Designs with features to prevent loss of spent fuel pool integrity as a result of an aircraft impact.

In response to this attribute, 4S is designed to satisfy the following conditions:

- The 4S reactor does not use a spent fuel pool.

- There is no refueling except at the beginning and end of the 30-year plant life.

(13) Attribute 13

Designs with features to eliminate or reduce the potential theft of nuclear materials.

In response to this attribute, 4S is designed to satisfy the following conditions:

- New and spent fuel is not stored onsite.
- Fuel handling equipment is not kept onsite.

(14) Attribute 14

Designs that emphasize passive barriers to potential theft of nuclear materials.

In response to this attribute, 4S is designed to satisfy the following conditions:

- Below-grade installation of the reactor building

Table 3.1
Response to SECY-10-0034 (1/22)

Sec. No.	SECY-10-0034 "Potential policy, licensing, and key technical issues for small modular nuclear reactor designs"	Response from Toshiba
2	Licensing Process issues for Small Modular Nuclear Reactor	
2.1	Licensing for Prototype Reactors	
	If the progress of an SMR research and development (R&D) program does not fully support an NRC decision on a license application for the proposed commercial version of the design, the design or operation of the first unit may need to include preventive or mitigative compensatory measures to account for uncertainties in the design or operational capability (see 10 CFR 50.43(e)). In addition, the NRC may require special confirmatory tests and measurements in the license in order to confirm that the facility operates in accordance with the designer's analyses. License conditions could be imposed and/or features added to the plant to increase safety margin until such time as the operation of the prototype unit or other testing programs confirm certain aspects of the design and equipment performance. These license conditions could, for example, limit the plant to less than full power, place restrictions on operational temperature, or require more extensive startup or operational testing. Another alternative could be to use initial plant startup as a means to test and confirm plant safety features in lieu of conducting R&D before plant licensing. If such an alternative is chosen, the scope and nature of the startup or operational test program would need to be agreed upon, but this alternative could involve an incremental licensing approach during startup operations, with power and temperature uprates allowed when confirmatory measurements of core temperature and plant parameters confirm design expectations and predictions. License applicants and the NRC staff have not relied on the construction and operation of a licensed prototype reactor to confirm design assumptions or to even supplement pre-licensing R&D since the early period of the evolution of commercial nuclear power plants. The use of these provisions in NRC regulations may involve policy issues for Commission consideration. The NRC staff also discussed this issue in SECY-02-0180.	Currently Toshiba plans to apply for DA of the 4S reactor based on Subpart E to 10 CFR 52[14]. The 4S, a sodium-cooled fast reactor using metallic fuel, can be commercialized without the need for demonstration tests using a prototype reactor. The 4S safety case will be sufficiently complete to immediately commence the review for the licensing of the reactor based on following experience: • ~400 Reactor years of operating experience of SFRs based on Reference 15. • Extensive data base of irradiated metallic fuel in the US (over 40,000 metallic fuel pins and over 16,000 U-Zr metallic fuel pins[7]). • Safety tests of ATWS events that have been successfully performed at the EBR-II (metal fueled sodium cooled reactor) to demonstrate the effectiveness of inherent reactivity feedback mechanisms. • Demonstration tests of the evolutionary design components that have been performed or are in progress or planned:

Table 3.1
Response to SECY-10-0034 (2/22)

Sec. No.	SECY-10-0034 "Potential policy, licensing, and key technical issues for small modular nuclear reactor designs"	Response from Toshiba
2.1 (cont.)	This issue was raised as a potential issue for the NGNP in the August 2008 Licensing Strategy, but the staff believes that it could also be applicable to other new, first-of-a-kind designs. The staff believes that resolution for this issue need not occur until after a license application is submitted because the extent of necessary preventive or mitigative compensatory measures and confirmatory testing needs for a prototype will not be known until after the staff has reviewed the applicant's demonstration test program for the design and the proposed operational test program that supports the license. Once a license application is received, the NRC staff will review the prototype design, consider white papers or topical reports concerning this issue that it receives from DOE and potential SMR applicants, discuss design-specific proposals to address this matter, and determine whether compensatory measures are needed for the design to account for uncertainties in design or operational capability of the facility. Should it be necessary, the staff will propose changes to existing regulatory guidance or new guidance concerning the license for the prototype in a timeframe consistent with the licensing schedule.	Nuclear design issues such as criticality, sodium void reactivity and reflector reactivity has been validated for the reflector controlled core by using mockup of 4S core at Fast Critical Assembly (FCA). Design methodology of the flow and pump head has been validated by immersed-type full scale EM pump. The validation of the design methodology of EM flow meter is in progress. Heat transfer coefficient between reactor vessel and air has been evaluated for RVACS. The manufacturing technology of double wall tube for steam generator was obtained, and that of the steam generator leak detection is in progress[11, 16]. The 4S will base its safety case also in part on the applicable regulations in 10 CFR Parts 20, 50, 73, and 100, Regulatory Guides, SRP, the Safety Evaluation Reports of the CRBR and the PRISM SFRs, and applicable codes and standards[17, 18, 19, 20, 21, 22, 23]. The issue of the operating license of the first commercial reactor will be evaluated after the NRC issues its safety evaluation report related to the 4S DA. A system mock-up test before plant construction and initial plant startup tests such as reactivity test and safety performance test may be conducted.

Table 3.1
Response to SECY-10-0034 (3/22)

Sec. No.	SECY-10-0034 "Potential policy, licensing, and key technical issues for small modular nuclear reactor designs"	Response from Toshiba
3	Issues Concerning Design Requirements for Small Modular Nuclear Reactors	
3.1	Implementation of the Defense-In-Depth Philosophy for Advanced Reactors	
	The Commission has had a long-standing policy of ensuring that defense-in-depth (DID) is incorporated into the design and operation of nuclear power plants. The requirements in 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," incorporate DID measures specific to LWRs (e.g., a pressure-retaining, low-leakage containment). Although integral SMRs employ the more traditional DID approach of LWRs in their designs, non-LWR SMR designers propose to use different approaches to establish DID barriers for their designs. This can be seen in their approaches to address technical issues such as redundancy of key safety-related components and containment functional capability. For non-LWRs licensed in the past (e.g., Fort St. Vrain), DID measures have been determined on a case-by-case basis. Preventive or mitigative compensatory measures may need to be incorporated into the design or operation of certain SMRs to account for uncertainties in design or operational capability of the facility. Therefore, the NRC staff will need to determine appropriate DID measures and develop appropriate requirements and guidance to support design and license reviews of integral PWRs and non-LWR designs.	The 4S implements the DID philosophy defined by the NRC[5]. At the same time, the 4S design process has the requirement to meet the objectives of Attributes 4, 8 and 10 of the Policy Statement on the Regulation of Advanced Reactors discussed in Section 3.2 of this report, namely: • Minimize the potential for severe accidents and their consequences, with emphasis on minimizing the potential for accidents over minimizing the consequences of such accidents (Attribute 4) • Maintain multiple barriers against radiation release, and reduce the potential for and consequences of severe accidents (Attribute 8) • Include considerations for safety and security requirements together in the design process (Attribute 10)

Table 3.1
Response to SECY-10-0034 (4/22)

Sec. No.	SECY-10-0034 "Potential policy, licensing, and key technical issues for small modular nuclear reactor designs"	Response from Toshiba
3.1 (cont.)	In SECY-09-0056, the NRC staff stated that it plans to integrate its position on DID with its positions on other policy and key technical issues for future reactor designs during its reviews. The staff plans to continue development of a position on DID along with development of other related Commission policy and technical positions, but it will defer activities to finalize a DID policy statement until it has gained additional experience and related insights from the NGNP or other non-LWR reviews. The NRC staff believes that resolution of this issue is required to support the design Development of the NGNP and potentially other SMR designs. Therefore, it has been assigned a high importance that should be addressed before submittal of the NGNP COL application. In FY 2010 and FY 2011, the NRC staff will review pre-application white papers and topical reports concerning DID that it receives from DOE and potential SMR applicants, discuss design-specific proposals to address this matter, consider approaches to DID proposed by the domestic and international community, and determine whether preventive or mitigative compensatory measures may be needed for SMR designs to account for uncertainties in design or operational capability of the facility. Should it be necessary, the staff will propose changes to existing regulatory guidance or new guidance concerning DID in FY 2011 to support development of the NGNP or other SMR designs.	In order to evaluate the uncertainties specific to the new design features and to reduce these uncertainties and their impact, the following approaches are used: • PIRT[10] (to evaluate and identify important uncertainties and options for their reduction) • Experiments and lessons learned from operating LMRs such as EBR-II and Monju (for analysis code verification and validation) • Demonstration test using the sodium loop (to reduce the uncertainties in innovative components such as EM pump and DWSG)
3.2	Use of Probabilistic Risk Assessment in the Licensing Process for SMRs	
	In the August 2008 NGNP licensing strategy, the Commission concluded that the best option for licensing the NGNP prototype would be to use a risk-informed and performance-based technical approach that employs the use of deterministic judgment and analysis, complemented by NGNP-specific PRA information. This licensing approach would, where possible, adapt the existing LWR technical requirements to address the acceptability of the NGNP design and establish requirements unique to the NGNP for those technical areas that existing LWR requirements and guidance do not address. The Commission concluded that once	The 4S is designed using deterministic judgment and analysis, complemented by 4S-specific risk insights available at the DA application stage.

Table 3.1
Response to SECY-10-0034 (5/22)

Sec. No.	SECY-10-0034 "Potential policy, licensing, and key technical issues for small modular nuclear reactor designs"	Response from Toshiba
3.2 (cont.)	NGNP technology is successfully demonstrated through operation and testing of the NGNP prototype, and a quality PRA that includes data from operation of the prototype becomes available, greater emphasis on a design-specific PRA to establish the licensing basis and requirements will be a more viable option for licensing a commercial version of the NGNP reactor. Design development and possible review approaches have been discussed with the NRC and proposed in other forums (i.e., draft consensus standards and international technical reports) that would place greater emphasis on the use of risk insights to identify licensing basis events and establish the safety classification of systems, structures, and components (SSCs) for reactor designs. This approach is consistent with a licensing approach described in SECY-03-0047 and approved by the Commission in its staff requirements memorandum (SRM) of June 26, 2003. However, in SECY-09-0056, the NRC staff discussed its plans to follow an approach consistent with the NGNP Licensing Strategy for licensing the prototype reactor while also testing and refining requirements and guidance for increased use of risk insights in the licensing process. Should an applicant submit a design for a facility license that uses an approach applying increased use of risk insights to establish the licensing basis before this effort is undertaken and evaluated, the use of this approach may involve policy issues requiring Commission consideration. In addition, a number of issues related to the application of current risk-informed programs have been raised because of the lower risk estimates for the large LWRs currently under review. The two most common risk metrics used in current risk-informed applications are based on a core damage frequency (CDF) of 10^{-4}/year and a large, early release frequency (LERF) of 10^{-5}/year as surrogates for the Commission's quantitative health objectives. Risk estimates for new reactors are several orders of magnitude (1 to 3 for CDF; and 1 to 4 for radionuclide release frequency) lower than those for current designs when including internally initiated events and those externally initiated events that have been quantified. The lower risk values create challenges regarding how to apply acceptance guidelines for changes to the licensing basis and thresholds in the Reactor Oversight Process (ROP).	-

Table 3.1
Response to SECY-10-0034 (6/22)

Sec. No.	SECY-10-0034 "Potential policy, licensing, and key technical issues for small modular nuclear reactor designs"	Response from Toshiba
3.2 (cont.)	The NRC staff provided a white paper to the Commission on February 12, 2009, that identifies the issues posed by the lower risk estimates for large LWRs in risk-informed applications and potential options for implementation. On March 27, 2009, NEI submitted its own white paper recommending no change to the current risk metrics. The NRC staff held a meeting to discuss these issues with stakeholders on September 29, 2009, and is drafting a Commission paper to discuss the issue and present policy options to the Commission. These issues are expected to be applicable to integral PWRs as well. However, these risk metrics are not applicable to non-LWR SMRs, so the NRC will need to determine what risk metrics should be used for changes to the licensing basis and thresholds in the ROP for those designs. Because the NRC has chosen to use a risk-informed and performance-based technical approach that employs the use of deterministic judgment and analysis, complemented by design-specific PRA information to review the first NGNP, resolution of this issue is not required to conduct the COL review described in the NGNP Licensing Strategy. In addition, the staff plans to employ a similar approach to review design and license applications for integral PWR designs. Therefore, the staff believes that resolution of this issue need not occur until after design or licensing applications are submitted that propose a review approach be used by the NRC staff that places greater emphasis on a design-specific PRA to establish the licensing basis and requirements.	-
3.3	Appropriate Source Term, Dose Calculations, and Siting for SMRs	
	Accident source terms are used for the assessment of the effectiveness of the containment and plant mitigation features, site suitability, and emergency planning. Other radiological source terms are used to show compliance with regulations on dose to workers and the public. The Commission has previously deliberated on the use of design-specific and event-specific source terms, provided there was sufficient understanding and assurance of plant and fuel performance and deterministic engineering judgment was used to bound uncertainties.	The source terms for SFRs have been already discussed during the review of CRBR and PRISM. According to the evaluation of accident sequences of 4S, there is no sequences result in core melt whose occurrence frequency is equivalent to the frequencies discussed at previous licensing process in the US[24, 25].

Table 3.1
Response to SECY-10-0034 (7/22)

Sec. No.	SECY-10-0034 "Potential policy, licensing, and key technical issues for small modular nuclear reactor designs"	Response from Toshiba
3.3 (cont.)	The source terms for the integral PWRs may be based partly on source term information from current generation LWRs and insights gained from extensive state-of-the-art fission product experiments conducted to understand accident phenomena including fission product transport and release. The staff will assess what will be necessary to establish the basis for a scenario-specific approach and how uncertainties should be taken into account. In addition, design and license applicants and the NRC will need to establish appropriate bounding source terms for high-temperature gas-cooled reactors (HTGRs) and SFRs. This is discussed in more detail in Section 3.4 of this paper. There may be regulatory issues that the Commission may have to consider regarding whether the site boundary dose acceptance criteria and associated dose calculations for use in evaluation of site suitability and emergency planning for SMR designs should be updated or amended, or whether new requirements should be established for SMRs. Current regulatory practice employs the siting dose criteria in 10 CFR 50.34 and 10 CFR Part 52 in conjunction with deterministic design basis accident analyses as the key input parameters for analyzing the effectiveness of the containment, determining site suitability, and preparing site emergency plans. As discussed in the footnotes in 10 CFR 52.79(a), the current regulations on siting are based on deterministic evaluation of a large fission product release from a substantially melted core to an intact containment, with design leakage to the environment and calculation of cumulative dose to a reference person at two different locations offsite. These accident assumptions may not be applicable for some SMR designs, which may call into question the applicability of the dose criteria as well. In addition to the appropriate source terms for the SMR designs, the evaluation of site suitability may include consideration of the population density; use of the site environs, including proximity to man-made hazards; and the physical characteristics of the site, including seismology, meteorology, geology, and hydrology for the SMR designs.	This is because the 4S design emphasis on prevention of SAs. It means that the source terms at the failure in the scram systems that are discussed for CRBR and PRISM are not applicable to 4S. The source terms for 4S are preliminary determined non-mechanistically assuming 100% failure of the fuel cladding. The source terms pertain to the DBAs, where the containment may not be leak-tight, are also evaluated to cover non-core accidents at fission product (FP) release evaluation. The source term issues associated with the multi-module SMRs is not applicable to 4S since Toshiba plans to apply for a single-unit use of 4S for DA. Thus, the licensing issue for 4S is how to determine the design-specific and event-specific source terms for the core which prevents core melt.

Table 3.1
Response to SECY-10-0034 (8/22)

Sec. No.	SECY-10-0034 "Potential policy, licensing, and key technical issues for small modular nuclear reactor designs"	Response from Toshiba
3.3 (cont.)	Therefore, there may be regulatory issues that the Commission may have to consider regarding whether the seismic and geologic siting criteria and earthquake engineering criteria should be updated or amended, or whether new requirements should be established for SMRs to incorporate advancements of earth science and earthquake engineering for use in evaluation of the site suitability for some SMR designs. There may also be source-term issues associated with the multi-module aspect of SMRs where modules share SSCs. For example, the Commission may have to determine when it would be appropriate to base the bounding source term on an accident in a single module and when could possible sharing of SSCs require the evaluation of core damage in and potential releases from more than one module. Issues related to source term and risk evaluations for multimodule facilities may relate to policy and therefore, require Commission consideration. The NRC staff believes that resolution of this issue is required to support the design development of the NGNP. Interrelated issues could also affect the design of integral PWRs. Therefore, it has been assigned a high importance that should be addressed before submittal of design or license applications of these technology groups. In FY 2010 and FY 2011, the NRC staff will review pre-application white papers and topical reports concerning source-term issues that it receives from DOE and potential SMR applicants, discuss design-specific proposals to address this matter, and consider research and development in this area (both by the domestic and the international community). Should it be necessary, the staff will propose changes to existing regulations or regulatory guidance or propose new guidance concerning the source term for an SMR in FY 2011 to support development of the NGNP, integral PWRs, or other SMR designs.	-

Table 3.1
Response to SECY-10-0034 (9/22)

Sec. No.	SECY-10-0034 "Potential policy, licensing, and key technical issues for small modular nuclear reactor designs"	Response from Toshiba
3.4	Key Component and System Issues for SMR	
	• Core Composition and Source Term Issues for SMRs As discussed in Section 3.3 of this paper, source terms are used for the assessment of the effectiveness of the containment and plant mitigation features, site suitability, and emergency planning. The source terms for the integral PWRs may be based partly on source-term information from current generation LWRs and insights gained from extensive state-of-the-art fission product experiments conducted to understand accident phenomena including fission product transport and release. In addition, license applicants and the NRC will need to establish appropriate bounding source terms for HTGRs and SFRs and the conditions under which their use can be justified in licensing. In SECY-93-0092, the NRC staff proposed that source terms for HTGRs and SFRs should be based upon a bounding mechanistic analysis that meets certain performance and modeling criteria supported by research and test data. The conditions under which the use of design-specific and event-specific mechanistic source terms can be justified and used in licensing non-LWRs will have to be supported by experimental data to confirm the parameters of the source term. In its SRM dated July 30, 1993, the Commission approved the staff's recommendation. The NRC staff will ensure that uncertainties are accounted for in the designs. Because of the implications of using design-specific and event-specific mechanistic source terms in licensing, the technical basis for and the uses of such source terms in licensing are critical to the resolution of this technical issue. In addition, differences in the core composition of non-LWRs could result in potential policy issues concerning fuel cycle and transportation impacts, including environmental impacts of the production, transportation, and storage of reactor fuel and radioactive waste for non-LWRs.	The source terms for 4S are discussed in Section 3.3. Regarding potential policy issue related to difference in the core composition, the 4S does not plan to have fuel storage onsite. The safety and security of fuel shipment and storage offsite will be submitted with the COL application.

Table 3.1
Response to SECY-10-0034 (10/22)

Sec. No.	SECY-10-0034 "Potential policy, licensing, and key technical issues for small modular nuclear reactor designs"	Response from Toshiba
3.4 (cont.)	In SECY-02-0180, the NRC staff recommended that the environmental effects of the production, transportation, and storage of reactor fuel and radioactive waste be reviewed on an application-by-application basis for non-LWR license applicants. The Commission approved the staff's recommendation in its SRM dated March 31, 2003.	-
3.4 (cont.)	• Accident Selection for SMRs For SMRs, the NRC staff will need to consider a different or revised set of accidents than those considered for current LWRs to provide a basis for selecting a mechanistic siting source term and for judging the adequacy of features such as containment functional design and offsite emergency planning. The NRC staff will need to consider accident scenarios during power ascension, full power operation, power decrease, and low power operations. In the August 2008 NGNP Licensing Strategy, the Commission stated that licensing-basis event categories (i.e., abnormal occurrences, design-basis accidents, and beyond-design basis accidents) would be established based on the expected probability of event occurrence. However, selection of licensing basis events within each category would be performed using deterministic engineering judgment complemented by insights from the NGNP PRA. In general, the NRC staff expects to apply this approach to all SMRs. Although identification of many accident scenarios will likely be straightforward, the application of certain scenarios may require Commission consideration. For example, designers of HTGRs have previously proposed that the failure of the vessel or piping connecting the reactor vessel and steam generator vessel need not be considered as a design basis event. In addition, although the Commission has previously stated that certain events should be addressed for non-LWR designs, subsequent research and evaluations may challenge the need to analyze these low probability events.	The 4S uses event categories similar to those of SRP[21] Chapter 15(AOO, DBA, and ATWS). FMEA and a MLD were used to identify critical failures especially those related to innovative designs and accident sequences that lead to AOO, DBA, and ATWS. Engineering judgment based on historic failure rate data[26, 27, 28,29], and the evaluation of events reported in licensing documents for the PRISM[23] and CRBR[22] was used to assign events to event categories.

Table 3.1
Response to SECY-10-0034 (11/22)

Sec. No.	SECY-10-0034 "Potential policy, licensing, and key technical issues for small modular nuclear reactor designs"	Response from Toshiba
3.4 (cont.)	• Redundancy of the Passive Residual Heat Removal System In SECY-93-0092, the NRC staff identified an issue regarding whether advanced reactor designs that rely on a single, completely passive, safety-related residual heat removal (RHR) system would be acceptable. The staff stated that the unique features of the PRISM and Modular High-Temperature Gas-Cooled Reactor (MHTGR) designs lead the NRC staff to believe that reliance on such an RHR system may be acceptable, depending on how the designer addresses this issue. In performing its detailed design evaluation, the NRC staff committed to ensure that NRC regulatory treatment of non-safety-related backup RHR systems is consistent with Commission decisions on passive LWR design requirements. In its SRM dated July 30, 1993, the Commission approved the staff's approach. The NRC staff will ensure that treatment of proposed non-safety-related backup systems is adequately addressed in SMR designs.	The 4S reactor has two redundant and diverse RHRSs that remove heat to the environment by natural circulation and draft of air (RVACS and IRACS). RVACS is a completely passive system from initial plant start up through any other operating conditions afterwards. Though IRACS requires active action to open the dampers installed at the flow path of cooling air when needed, the passive residual heat removal is also possible by IRACS even one of the two dampers fails to open. The dampers incorporate fail-safe design, and both of the RHRSs are safety-related systems.

Table 3.1
Response to SECY-10-0034 (12/22)

Sec. No.	SECY-10-0034 "Potential policy, licensing, and key technical issues for small modular nuclear reactor designs"	Response from Toshiba
3.4 (cont.)	• Classification of Structures, Systems, and Components During its reviews of recent LWR design and license applications, the NRC staff has used deterministic judgment, complemented by insights from the design-specific PRA, to review SSCs relied on to prevent or mitigate safety-significant licensing-basis events. In conducting its review, the staff verified that safety margins were adequate to ensure the integrity and performance of safety-significant SSCs using a conservative analysis or a best-estimate analysis with consideration of uncertainties. The NRC staff expects to apply this approach to most of the SMR design reviews. If necessary, special treatment requirements would be established to ensure the required performance capability and reliability of the safety-significant SSCs, using deterministic engineering judgment, complemented by insights and information from the design-specific PRA. The NRC staff stated that it planned to use this approach to classify the SSCs for the NGNP in the August 2008 NGNP Licensing Strategy. However, as discussed in Section 3.2 of this paper, alternative approaches are being considered that put more emphasis on the use of risk insights that are complemented by deterministic evaluations and engineering judgment. DOE or an SMR designer may propose such an approach to justify modification of the design, installation, and maintenance requirements of the identified safety-related SSCs. Once that policy issue is resolved, the NRC staff will ensure that it is adequately implemented when conducting its design or license reviews.	The 4S SSCs are classified by deterministic judgment complemented by 4S-specific risk insights available at the DA application stage.

Table 3.1
Response to SECY-10-0034 (13/22)

Sec. No.	SECY-10-0034 "Potential policy, licensing, and key technical issues for small modular nuclear reactor designs"	Response from Toshiba
3.4 (cont.)	• Containment Functional Capability for SMRs Fission product retention during an accident involving an HTGR will be highly dependent upon the ability of its coated fuel particles to maintain their integrity and retain fission products during normal operation and accident conditions. Previous gas-cooled reactor designs have relied on similar coated fuel particle technology and have demonstrated the feasibility of using fuel as the primary barrier to fission product release. SFR designers rely on their fuel characteristics and cladding, the reactor vessel, and a containment system that is expected to be exposed to low pressures during an accident to provide multiple barriers to retain fission products. The IRIS and mPower LWR designs employ more conventional LWR barrier designs, relying on their fuel cladding, the reactor coolant pressure boundary, and containment design to retain fission products, and are not expected to raise policy issues in this area. However, the NuScale LWR design employs a non-traditional, small containment for each module that operates in a large pool of water. This unique design could raise construction and operational issues that must be adequately addressed by the designer. In SECY-03-0047, the NRC staff recommended that the Commission approve the use of functional performance requirements to establish the acceptability of a containment or confinement structure (i.e., consideration of a non-pressure-retaining building provided certain performance requirements can be met). In developing the requirements for SMRs, the need for and type of containment barrier will have to be established. This will involve taking into consideration factors such as fuel quality and performance, plant transient behavior, security, aircraft impact assessments, and DID. In an SRM to SECY-03-0047, the Commission disapproved the staff's recommendation related to the requirement for a pressure-retaining containment building, but directed the staff to pursue the development of functional performance standards and then submit options and recommendations to the Commission on this issue. The variety of designs currently being proposed may result in this issue being brought before the Commission for resolution on specific designs or groups of designs.	The 4S containment has several features to ensure its structural integrity against internal and external hazards. The containment is inerted, and intermediate sodium piping passing through it has guard piping to ensure the prevention of sodium fire. The containment has minimal penetrations and design leak rate will be confirmed by periodic testing. The containment is seismically isolated and placed below grade which protects it from aircraft impact and terrorist attacks. As stated under the source term issue, the containment is one of three structural barriers against the release of FPs.

Table 3.1
Response to SECY-10-0034 (14/22)

Sec. No.	SECY-10-0034 "Potential policy, licensing, and key technical issues for small modular nuclear reactor designs"	Response from Toshiba
4	Operational Issues for Small Modular Nuclear Reactors	
4.1	Appropriate Requirements for Operating Staffing for Small or Multi-Module Facilities	
	Some SMR designs may use multiple modules at one site, but current regulations do not address the possibility of more than two reactors being controlled from one control room. In SECY-93-0092 and SECY-02-0180, the NRC staff discussed whether advanced reactor designs should be allowed to control more than two reactors from one control room and operate with a staffing complement that is less than that currently required by the Commission's regulations. The NRC staff stated that it believed that operator staffing may be design dependent and intended to review the justification for a smaller crew size for the advanced reactor designs by evaluating the function and task analyses for normal operation and accident management. In SECY-93-0092, the staff identified several factors that could be used in assessing the staffing levels for SMRs, including the following: • Whether smaller operating crews could respond effectively to a worst-case array of power maneuvers, refueling and maintenance activities, and accident conditions. • Whether an accident at a single unit could be mitigated with the proposed number of licensed operators, less one, while all other units could be taken to a cold-shutdown condition from a variety of potential operating conditions, including a fire in one unit. Whether the units could be safely shut down with eventual progression to a safe shutdown condition under each of the following conditions: (1) a complete loss of computer control capability, (2) a complete station blackout, or (3) a design-basis seismic event. The NRC staff also concluded that an "actual control room prototype" should be used for test and demonstration purposes. In its SRM dated July 30, 1993, the Commission approved the staff's recommendation.	This issue is not applicable to 4S, because 4S is not designed for modular use. Toshiba plans to apply for a single-unit use of 4S for DA. Regarding operator staffing, Toshiba will justify any requests for exemption from current requirements using detailed design specific function and task analyses.

Table 3.1
Response to SECY-10-0034 (15/22)

Sec. No.	SECY-10-0034 "Potential policy, licensing, and key technical issues for small modular nuclear reactor designs"	Response from Toshiba
4.1 (cont.)	Other potential SMR policy issues include the possible need for requirements on control room staffing during refueling operations, reactor staff who interact with an interconnected manufacturing plant, supervisory staff, shift work, and training. During pre-application discussions with the NRC staff, SMR designers have indicated that they are evaluating whether the function and task analyses for normal operation and accident management conducted for their SMR designs support control of more than two modules from one control room and support operation with a staffing complement that is less than that currently required by the Commission's regulations. The NRC staff believes that resolution of this issue is required to support the design development, and the staff's review, of design and license applications for most of the SMR designs, including the NGNP. The staff intends to re-assess and revise, as needed, the earlier staff technical positions and plans for resolving the operator staffing issue for SMR designs. Therefore, the issues have been assigned a high importance that should be addressed before submittal of design or license applications of these technology groups. In FY 2010 and FY 2011, the NRC staff will review pre-application white papers and topical reports concerning operator staffing and associated control room design that it receives from DOE and potential SMR applicants, discuss design-specific proposals to address this matter, discuss the proposed resolutions with human factors and instrument and controls experts, and consider research and development in this area (both by the domestic and the international community). Should it be necessary, the staff will propose changes to existing regulatory guidance or staff positions or propose new guidance concerning the operator staffing for an SMR in FY 2012 to support development of the NGNP, integral PWRs, or other SMR designs.	-

Table 3.1
Response to SECY-10-0034 (16/22)

Sec. No.	SECY-10-0034 "Potential policy, licensing, and key technical issues for small modular nuclear reactor designs"	Response from Toshiba
4.3	Installation of Reactor Modules During Operation for Multi-Module Facilities	
	The multi-module aspect of certain SMR designs allows modules to be added to the facility while modules that were installed earlier are operating. This type of evolution and possible effects on shared systems and structures could raise policy issues requiring Commission consideration before final decisions regarding the acceptability of a design or issuance of a license are made. This issue is applicable to license applications for certain integral PWRs. However, the staff believes that resolution for this issue need not occur until after a license application is submitted because it concerns activities that will need to be addressed near the end of an operating license review. Once a license application is received, the NRC staff will review the proposed installation scenario for the facility, consider white papers or topical reports concerning this issue that it receives from the SMR applicant, discuss design-specific proposals to address this matter, and determine the acceptability of the applicant's proposed installation proposal. Should it be necessary, the staff will propose resolutions changes to existing regulatory guidance or new guidance concerning this operational program for the facility in a timeframe consistent with the licensing schedule.	This issue is not applicable to 4S, because 4S is not designed for modular use.

Table 3.1
Response to SECY-10-0034 (17/22)

Sec. No.	SECY-10-0034 "Potential policy, licensing, and key technical issues for small modular nuclear reactor designs"	Response from Toshiba
4.4	Industrial Facilities Using Nuclear-Generated Process Heat	
	Besides generating electricity, SMRs provide a possible source of process heat for industrial uses because of their size, high heat production, and capability to be located in remote areas. SMRs are being considered for such industrial uses as producing process heat for chemical plants, refineries, desalinization plants, hydrogen production facilities, and bitumen recovery from oil sands. The NRC staff has identified potential policy and licensing issues for those facilities used to provide process heat for industrial applications. The close coupling of the nuclear and process facilities raises concerns involving interface requirements and regulatory jurisdiction issues. Effects of the reactor on the commercial product of the industrial facility during normal operation must also be considered. For example, tritium could migrate to a hydrogen production facility and become a byproduct component of the hydrogen product. Resolution of these issues will require interfacing with other government agencies and may require Commission input to determine whether the design and ultimate use of the product is acceptable. This issue is applicable to license applications for new, first-of-a-kind SMR designs, including the NGNP. However, the staff believes that resolution for this issue need not occur until after a license application is submitted because it concerns site-specific issues associated with the staff's review of an operating license. Once a license application is received, the NRC staff will review how the nuclear facility is connected to the industrial facility, consider the interrelationship between the staffs of both facility, consider white papers or topical reports concerning this issue that it receives from DOE and potential SMR applicants, discuss design-specific proposals to address this matter, and review similar activities with nuclear and non-nuclear facilities. Should it be necessary, the staff will propose changes to existing regulatory guidance or new guidance concerning the effect of the industrial facility on the nuclear facility in a timeframe consistent with the licensing schedule.	This issue is not applicable to the DA phase. Besides, the 4S DA application will be for generating electricity with a turbine system. In case the need arises for a process heat use, the issue will be discussed on a case-by-case basis at the COL application stage.

Table 3.1
Response to SECY-10-0034 (18/22)

Sec. No.	SECY-10-0034 "Potential policy, licensing, and key technical issues for small modular nuclear reactor designs"	Response from Toshiba
4.5	Security and Safeguards Requirements for SMRs	
	Traditionally, the approach for security to comply with 10 CFR Part 73, "Physical Protection of Plants and Materials," has largely been one of assessing a plant design and overlaying security provisions (e.g., fences, locked doors, guards) on that design. For SMRs, traditional security provisions could be similar to those for current LWRs. Similarly, material control and accounting (MC&A) safeguards requirements for reactors have been limited to the recordkeeping and other related requirements in 10 CFR 74.19, "Recordkeeping." These would be appropriate and applicable for most of the SMRs. However, SMRs with unique fuel handling requirements may require special licensing requirements for MC&A. However, since September 11, 2001, it has been recognized that a stronger tie between design and security would be useful so as to integrate the resolution of security issues during the design process. Because many SMRs are still in early developmental stages and the designs are not yet fixed, the designers have a unique opportunity to determine the appropriate design basis threat; develop emergency preparedness; and integrate physical security protection, cyber security protection, and MC&A measures with the design and operational requirements during the design process and during the development of a license applicant's physical security and MC&A programs and systems. Therefore, SMR designers are expected to integrate security into the design and will need to conduct a security assessment to evaluate the level of protection provided, including safeguards aspects of SMR-related fuel cycle and transportation activities.	The 4S design reflects security considerations that have been integrated in the design process since the beginning of the design. For example, the reactor building is installed below grade to protect the integrity of the SSCs from external attack and terrorism. Another feature of the 4Sis that all the safety-related systems are designed not to depend on the functions of the auxiliary systems installed outside the reactor building. This ensures the integrity of the reactor safety-related systems in case auxiliary systems such as the feedwater system is attacked. The 4S design provides the safeguard of the nuclear materials as well. The reactor is designed with no need for refueling. Therefore, there is no onsite fuel storage, fuel transport and the reactor plug from which the fuel can be taken out is sealed during operation, and it can be welded if necessary. That makes the access from outside to the nuclear material difficult for intruders during operation.

Table 3.1
Response to SECY-10-0034 (19/22)

Sec. No.	SECY-10-0034 "Potential policy, licensing, and key technical issues for small modular nuclear reactor designs"	Response from Toshiba
4.5 (cont.)	The small size, reduced number of vital areas, and design approaches that incorporate safety systems underground that characterize the SMR designs have led DOE, SMR designers, and potential SMR operators to raise issues regarding the appropriate number of security staff and size of the protected area. The NRC will need to reevaluate the applicability of the appropriate performance and prescriptive regulatory requirements based on a variety of SMR designs, the design specific source terms to cause radiological sabotage, the enrichment and material forms of special nuclear material, and specific SMR design and license applications. These evaluations will likely require either design or site-specific justifications to support proposed relief from established regulatory requirements or consideration by the Commission before final decisions regarding the acceptability of a design or issuance of a license are made. The NRC staff believes that resolution of this issue is required to support the design development of the NGNP, integral PWRs, and other SMR designs. Therefore, it has been assigned a high importance that should be addressed before submittal of design or license applications of these technology groups. In FY 2010 and FY 2011, the NRC staff will review pre-application white papers and topical reports concerning safeguards that it receives from DOE and potential SMR applicants, discuss design-specific proposals to address this matter, discuss the proposed resolutions with safeguards experts, and consider research and development in this area (both by the domestic and the international community). Should it be necessary, the staff will propose changes to existing regulatory guidance or new guidance concerning safeguards for an SMR in FY 2011 to support development of the NGNP, integral PWRs, or other SMR designs.	-

Table 3.1
Response to SECY-10-0034 (20/22)

Sec. No.	SECY-10-0034 "Potential policy, licensing, and key technical issues for small modular nuclear reactor designs"	Response from Toshiba
4.6	Aircraft Impact Assessment for SMRs	
	On June 12, 2009, the Commission promulgated the Aircraft Impact Rule (74 FR 28112), which requires design and license applicants for new nuclear power reactors to perform a rigorous assessment of their designs to identify design features and functional capabilities that could provide additional inherent protection to avoid or mitigate the effects of an aircraft impact. The applicant is required to identify and incorporate into the design those design features and functional capabilities that avoid or mitigate, to the extent practical and with reduced reliance on operator actions, the effects of the aircraft impact on key safety functions. The applicant is required to show that, with reduced operator actions: (1) the reactor core remains cooled, or the containment remains intact; and (2) spent fuel pool cooling or spent fuel pool integrity is maintained. In its Statement of Considerations for rulemaking, the NRC acknowledged that these requirements may not be applicable to non-LWR designs, or may have to be supplemented by other key functions. When reviewing non-LWR designs, the NRC will evaluate the applicability of the acceptance criteria set forth in the aircraft impact rule and the possible need for other criteria. If necessary, the NRC will issue exemptions and impose supplemental criteria in a design certification or license to be used in the aircraft impact assessment for such non-LWR designs. Aircraft impact assessments may be needed for future small module design reactors. In addition, aircraft impact issues may have to be addressed for industrial facilities that are using nuclear-generated process heat. Proposed resolutions of this issue for an SMR may require Commission input to determine whether the design approach is in keeping with Commission policy on this issue. The NRC staff believes that resolution of this issue is required to support the design development of the NGNP, integral PWRs, and other SMR designs. Therefore, it has been assigned a high importance that should be addressed before submittal of design or license applications of these technology groups.	The 4S design incorporates the following features against aircraft impacts: • The residual heat of the core is removed by natural circulation of the coolant and natural air draft of the two independent and redundant stacks. The residual heat can be removed even if 50% of the stacks are blocked with rubble of the collapsed stack. • 4S has no spent fuel pool because it does not require refueling during operation. The containment vessel is installed below grade so that its integrity is maintained, and the radioactive materials will be retained in the containment vessel which is leaktight.

Table 3.1
Response to SECY-10-0034 (21/22)

Sec. No.	SECY-10-0034 "Potential policy, licensing, and key technical issues for small modular nuclear reactor designs"	Response from Toshiba
4.6 (cont.)	In FY 2010 and FY 2011, the NRC staff will review pre-application white papers and topical reports concerning aircraft impact assessments that it receives from DOE and potential SMR applicants, and discuss design-specific proposals to address this matter. Should it be necessary, the staff will propose changes to existing regulatory guidance or new guidance concerning aircraft impact assessments for SMRs in FY 2011 to support development of the NGNP, integral PWRs, or other SMR designs.	-
4.7	Offsite Emergency Planning Requirements for SMRs	
	In SECY-93-0092, the NRC staff questioned whether applicants for licenses referencing advanced reactors with passive design safety features should be able to adjust emergency planning zones (EPZs) and requirements. The staff proposed no changes to the existing regulations governing emergency planning for advanced reactor licensees, and stated that it would provide regulatory direction at or before the start of the design certification phase so that emergency planning implications on the design can be addressed. In its SRM dated July 30, 1993, the Commission stated that it was premature to reach a conclusion on emergency planning for advanced reactors and directed the NRC staff to use existing regulatory requirements. However, it instructed the staff to remain open to suggestions to simplify the emergency planning requirements for reactors that are designed with greater safety margins. Consideration of emergency preparedness by SMR developers is an essential element in the NRC's DID philosophy, which provides that, even in the unlikely event of an offsite fission product release, there is reasonable assurance that emergency protective actions can be taken to protect the population around nuclear power plants. However, the smaller size, lower power densities, lower probability of severe accidents, slower accident progression, and smaller offsite consequences per module that characterize SMR designs have led DOE, SMR designers, and potential SMR operators to raise questions regarding the appropriate size of the EPZ, the extent of onsite and offsite emergency planning, and the number of response staff needed.	The 4S EPZ is preliminary developed based on the following considerations[30]: Paragraphs in *italic* type are the excerpts from Reference 30. • *Projected doses from the traditional design basis accidents would not exceed protective action guide levels outside the zone.* • *Projected doses from most core melt sequences would not exceed Protective action guide levels outside the zone.* • *For the worst core melt sequences, immediate life threatening doses would generally not occur outside zone.* • *Detailed planning within 10 miles would provide a substantial base for expansion of response efforts in the event that this proved necessary.* There were no events in the traditional DBAs that result in a radiation dose more than 1rem outside the Exclusion Area Boundary

Table 3.1
Response to SECY-10-0034 (22/22)

Sec. No.	SECY-10-0034 "Potential policy, licensing, and key technical issues for small modular nuclear reactor designs"	Response from Toshiba
4.7 (cont.)	Other topics raised by the industry involve the potential to revise alert and notification requirements and the appropriateness of the protective action requirements in 10 CFR 50.47(b)(10) for SMRs. Although the NRC's current regulations allow for the review of requirements on a case-by-case basis, the Commission may wish to consider such changes for the many designs for which modification is justified. In addition, the applicants requesting certification of their reactor designs may seek finality by having approved changes in offsite emergency planning included as part of the design certification proceeding. Should the applicants propose deviation from NRC requirements, Commission input may be needed to determine whether the proposals are in keeping with Commission policy on this issue. This issue is applicable to license applications for new, first-of-a-kind SMR designs, including the NGNP. Although resolution of this issue may have a higher importance to an SMR license applicant trying to support its business case at the design certification stage, the staff believes that resolution of this issue may not involve design issues, and therefore, addressing such issues is more appropriate before the COL application stage. A change in the requirements for protective actions and the size of an EPZ is a policy issue that will be of interest to all stakeholders, including the Federal Emergency Management Agency (FEMA) and the public. Any changes to current policies would necessitate appropriate changes to the regulatory requirements and associated guidance documents. This effort would be needed in preparation for COL application reviews. Should it be necessary, the staff will propose changes to existing regulatory requirements and guidance or develop new guidance concerning reduction of offsite emergency preparedness for SMRs in a timeframe consistent with the licensing schedule.	(EAB). The 4S source terms are evaluated with the approach described in the clause 3.3, and then the subsequent FP release to the environment was evaluated based on the test data. The result showed that the the corresponding dose at the EAB was less than 1rem, and there are no regions which require evacuation outside the EAB. Thus, the issue for 4S is how to develop the emergency plan for the reactor with low occurrence frequencies of core melt accidents and no need for evacuation (i.e. EPZ < EAB). The 4S rated power is only 30 MW thermal. Based on this low rated power level and the above dose estimates Toshiba is planning to request from the NRC that issues related to the 4S emergency planning zone and emergency plans be treated as a special case in accordance with 10 CFR 50.47(c)(2)[31] which states: "*The size of the EPZs also may be determined on a case-by-case basis for gas-cooled nuclear reactors and for reactors with an authorized power level less than 250 MW thermal.*"

Table 3.2 Relationship between 4S design and attributes in 73 FR 60612

4S Design			Conformance to attributes													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
Reactor and core	Core		✓	✓		✓		✓	✓	✓		✓		✓		
	Reactivity control and shutdown system		✓		✓	✓				✓						
Reactor coolant system and connected systems	Reactor vessel								✓			✓				
	Shielding plug					✓		✓	✓	✓		✓				
	Guard vessel															
	Top dome				✓	✓			✓	✓						
	Reactor internal structure					✓		✓		✓						
	Primary heat transport system	General		✓		✓		✓	✓	✓						
		EM pump				✓	✓	✓		✓						
		IHX						✓								
	Intermediate heat transport system	General		✓		✓			✓	✓						
		EM pump					✓									
	Residual heat removal systems	IRACS	✓		✓	✓	✓			✓		✓				
		RVACS	✓		✓	✓	✓			✓		✓	✓			
Instrumentation and control	Reactor protection system			✓				✓				✓				
Auxiliary systems							✓									
Steam and power conversion system	DWSG			✓		✓				✓						
Building												✓	✓			✓
Reactor general	Human factors considerations have been incorporated				✓											
	Minimal electrical and electronic components							✓								
	Low maintenance primary components							✓								
	Remote in-service inspection								✓							
	Designs to satisfy DID philosophy									✓						
	Citation of existing technology										✓					
	Suitable technology development program based on the 4S PIRT										✓					
	No other fuel or fuel handling equipment onsite											✓			✓	
	No spent fuel pool														✓	

Table 3.3 Measures against Severe Accidents

Initiators	Measures of Risk Reduction
ATWS (ref. NUREG-0968 App. A[22])	Metallic fuel, negative feedback reactivity, and low power density
Sudden LOF without Scram (ref. NUREG-1368[23])	Metallic fuel, negative feedback reactivity, low power density, and natural circulation
All control rods withdrawal without scram (ref. NUREG-1368[23])	Redundant mechanical stops, very slow reactivity addition rate, and negative feedback reactivity
Fuel loading error (ref. NUREG-1368[23])	Similar enrichment level for both core regions (4S has two enrichment regions in core[12].)
Inlet blockage of subassemblies (ref. NUREG-1368[23])	No refueling, EM pump, and prevention by redundant flow path of inlet module
Gas passage in the core	Negative void reactivity feedback
75% blockage of flow path of RVACS (ref. NUREG-1368[23])	Backup redundant and diverse system (IRACS and RVACS)
Sodium water reaction	DWSG tube with leak detection
Failure of core support structure	Backup structure

Initiator	Design for Risk Reduction
Failure of cavity cans	Multiple cans

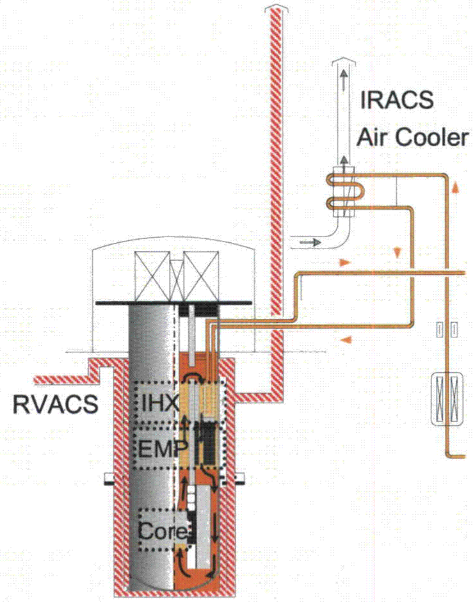


Fig. 3.1 Residual Heat Removal Systems

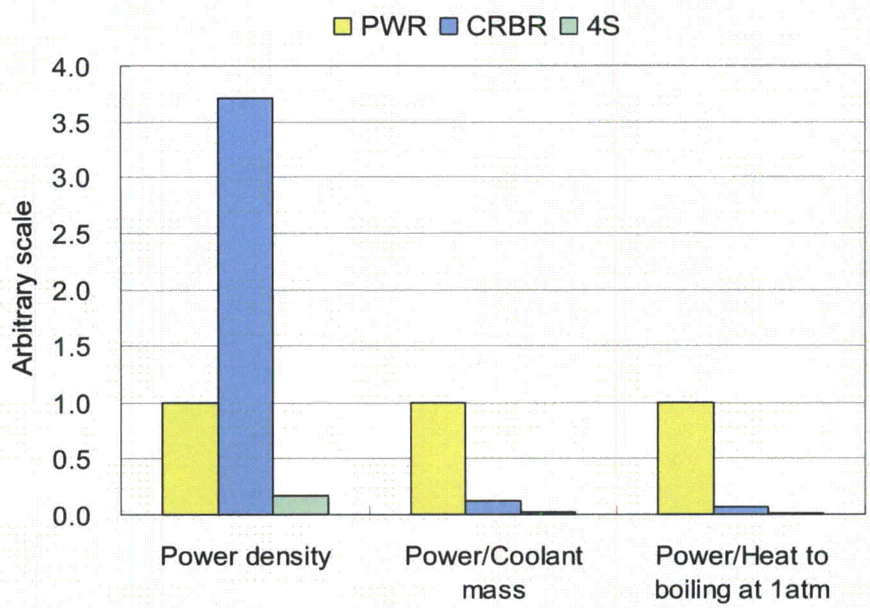


Fig. 3.2 Comparison of Design Features for PWR, CRBR, and 4S (based on Reference 32 and 33)

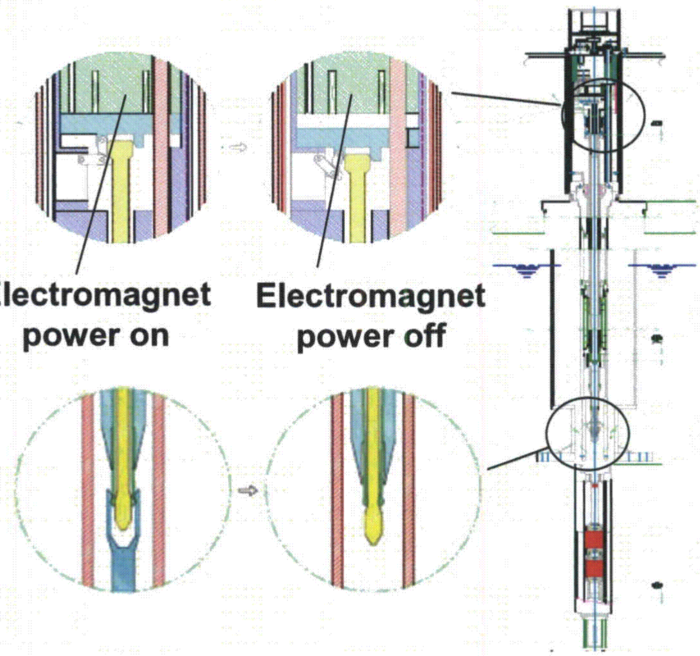


Fig. 3.3 Fail-Safe Shutdown Rod Drive System

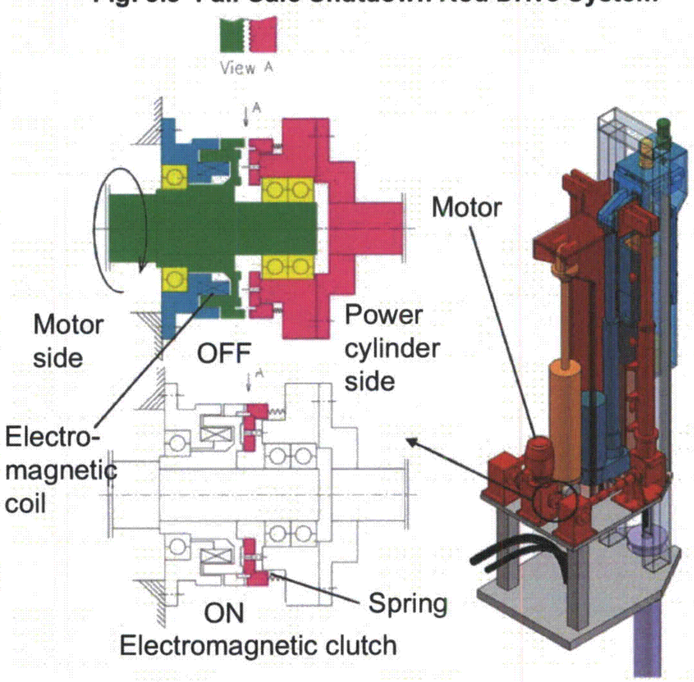


Fig. 3.4 Fail-Safe Reflector Drive System

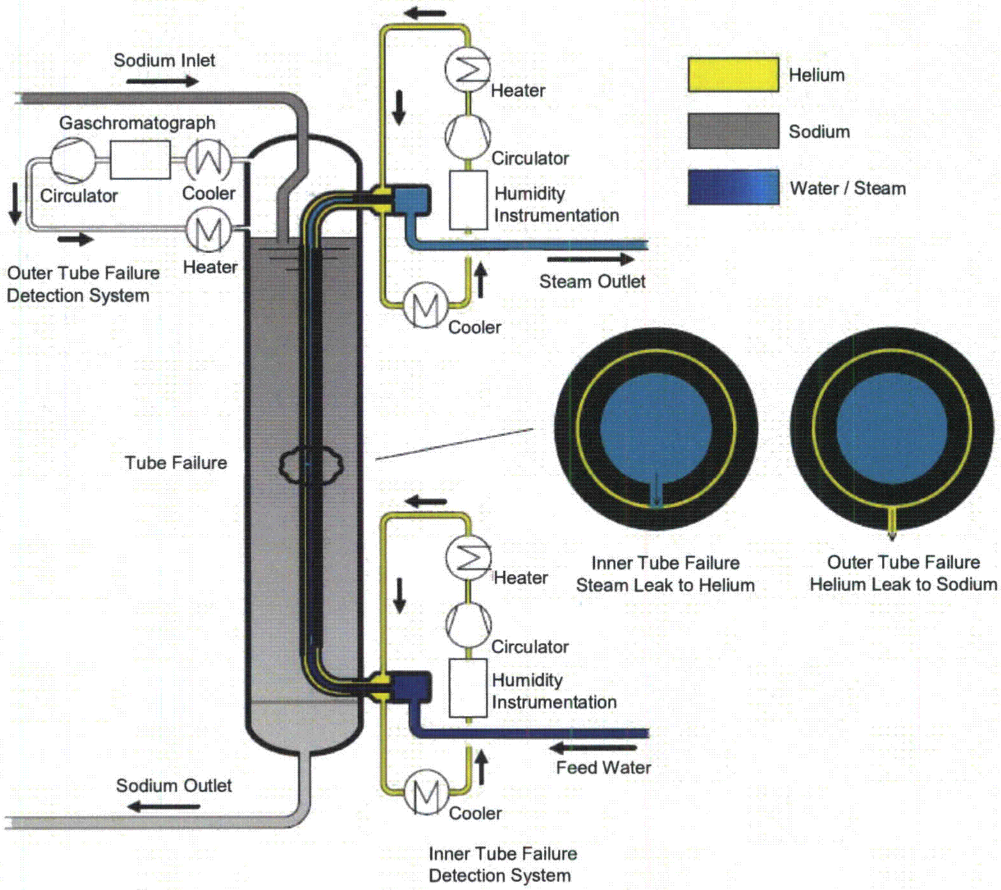


Fig. 3.5 Detection Systems of DWSG Tube Leak

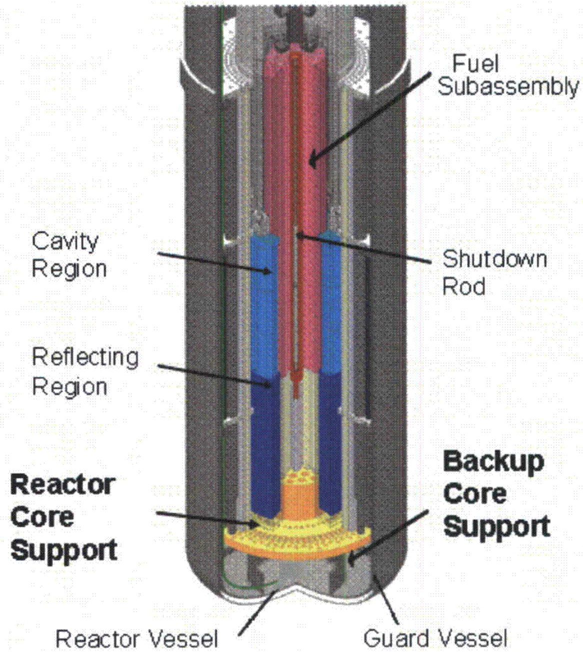


Fig. 3. 6 Backup Core Support Structure

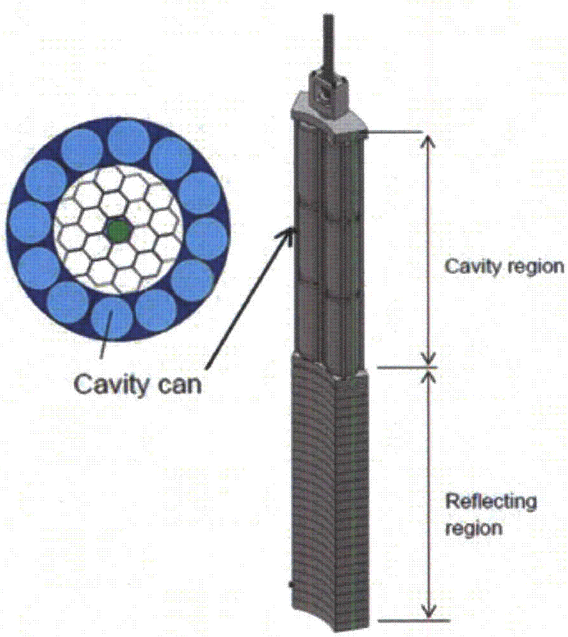


Fig. 3.7 Multiple Cavity Cans

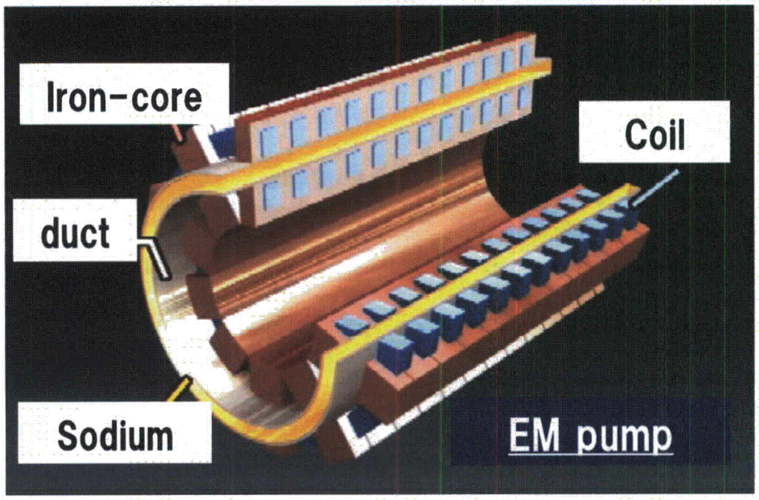


Fig. 3.8 Immersed-Type EM Pump of Primary Cooling System

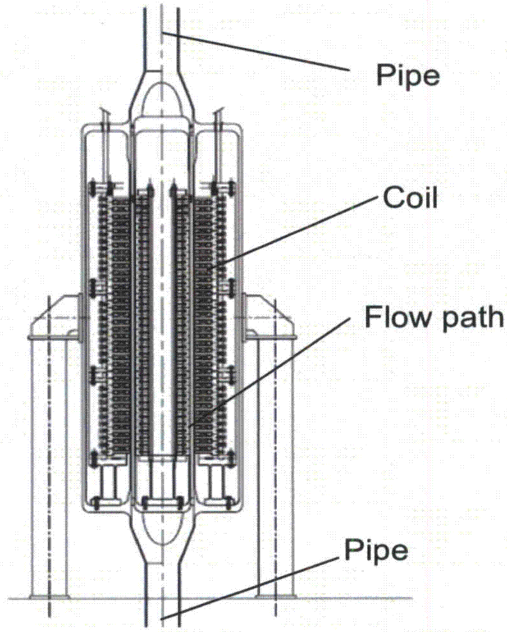


Fig. 3.9 Heat-Resistant EM Pump of Intermediate Cooling System

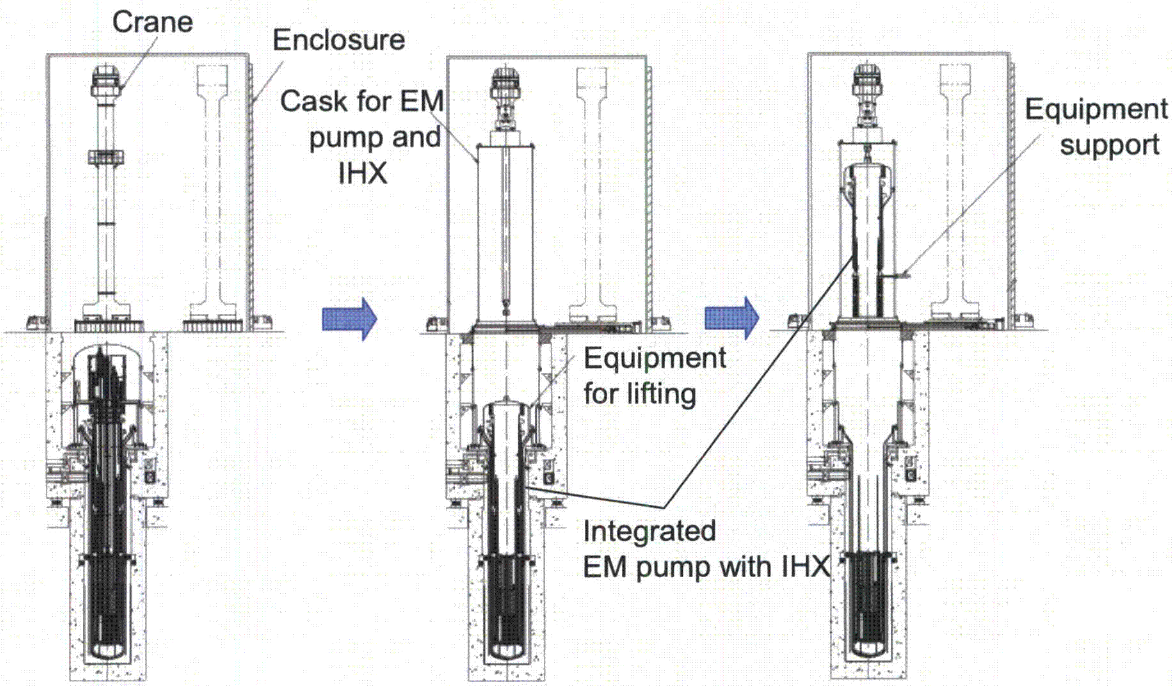
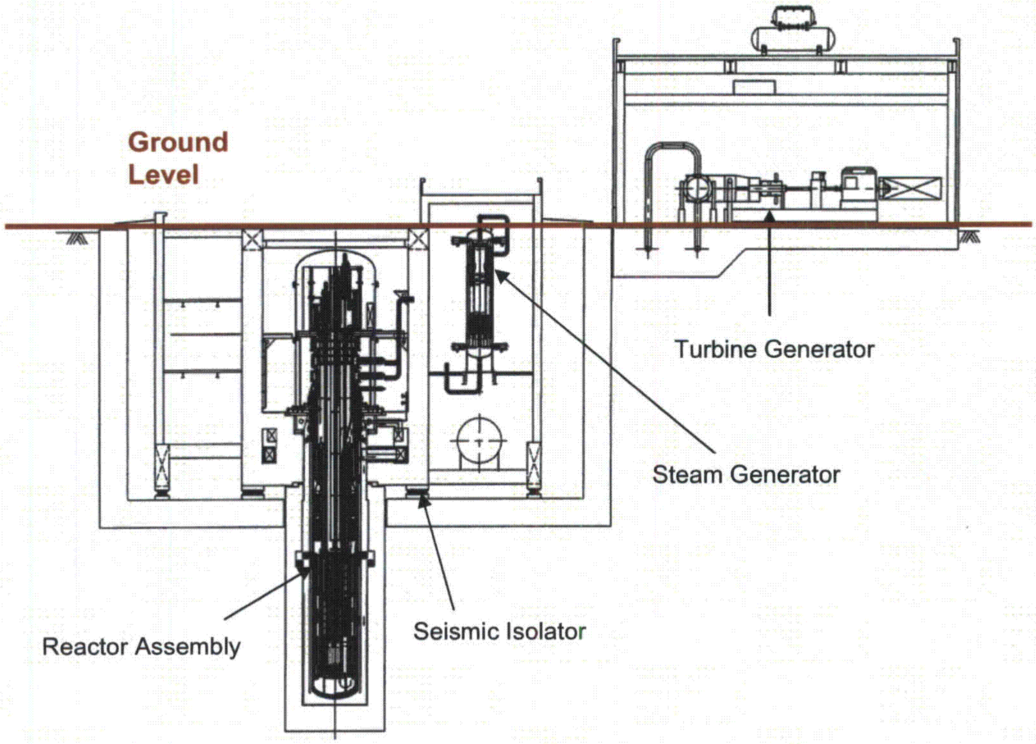


Fig. 3.10 Procedure for Removal/Replacement of Integrated EM Pumps and IHX



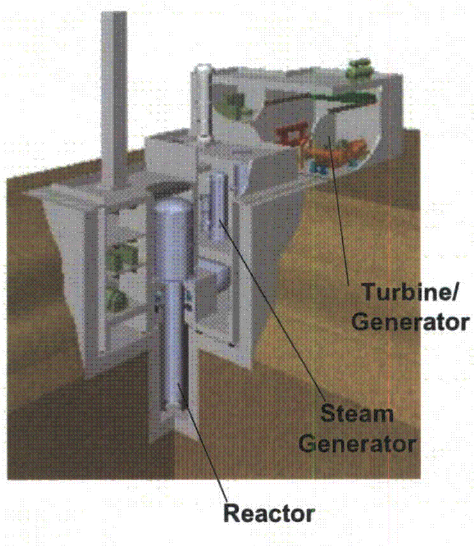


Fig. 3.11 Below-Grade Siting Layout

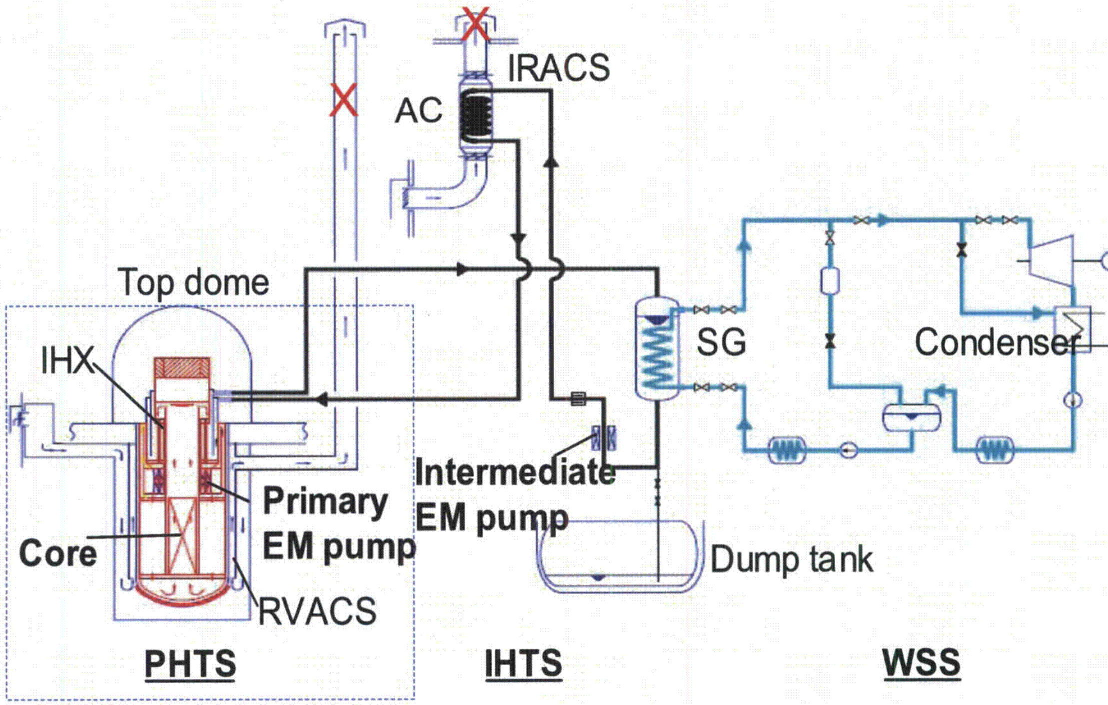


Fig. 3.12 Analysis Condition of Heat Removal after Aircraft Crash

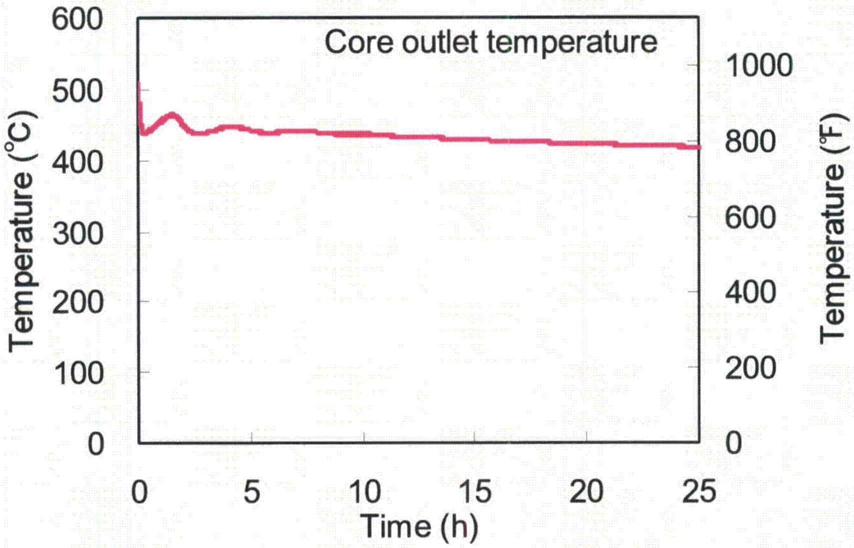


Fig. 3.13 Analysis Result of Heat Removal after Aircraft Crash

4 CONCLUSION

The policy issues pertaining to the SMRs and the responses against them are described in this report. Those issues include SECY-10-0034, "Potential policy, licensing, and key technical issues for small modular nuclear reactor designs" and 73 FR 60612, "Policy Statements on the Regulation of Advanced Reactors." It is demonstrated that the 4S design conforms to the policy statements for advanced reactors. As for the issues on SMR licensing, Toshiba expects to obtain NRC feedback on the responses reported herein during the ongoing pre-application review process.

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