



**IRCLASS**  
Indian Register of Shipping

# GUIDELINES ON **FLOATING NUCLEAR POWER PLANTS**

JULY 2026

# Guidelines

## Floating Nuclear Power Plants

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## **Introduction**

Nuclear Power Generation is a clean source of energy which can be used for various purposes. In this regard, nuclear reactors which are installed on a barge / pontoon which is moored nearshore or offshore for power generation are being considered for deployment. This document provides guidance on construction and classification of such floating nuclear power plants (FNPPs).

It is recognized that FNPPs are a novel concept being considered. The Guidelines are structured so as to take cognizance of this aspect and encourage innovation, however, with a view to maintaining an acceptable level of safety.

It is also recognized that certification of nuclear power plants is a matter which is addressed by the National Nuclear Regulatory Body and may also be subject to international requirements encompassing safety, security and safeguards of the International Atomic Energy Agency. The Guidelines acknowledge this aspect and mainly address the hull, non-nuclear machinery and mooring systems of the FNPP, while enabling them to provide a platform for the nuclear power plant to function safely in a marine environment.

Impact of the installation and operation of the nuclear power plant onboard is nevertheless covered in so far as the traditional role and purpose of Classification is concerned. The interfaces between the hull and non-nuclear machinery with the nuclear power plant are subject to IRS Classification requirements as well as any requirements by the National Nuclear Regulatory Body. Active co-operation between IRS and the statutory authorities such as the flag Administration, Coastal state and the National Nuclear Regulatory Body is anticipated in this regard to ensure adequate regulatory oversight. Wherever the phrase 'statutory requirements' is used in this document, it means that they refer to the requirements of the flag Administration, Coastal State and the National Nuclear Regulatory Body, as relevant and applicable.

These Guidelines are developed taking into account the relevant safety provisions in SOLAS Chapter VIII, the Code for Safety of Nuclear Merchant Ships (A.491(XII)) and the advances in nuclear technology. It is recognized that there is rapid advancement in nuclear technologies and therefore, it is endeavored to make these Guidelines technology agnostic. However, where requirements in this document may be restrictive to specific nuclear technology, such requirements have been indicated, and IRS will specially consider these.

## Section 1

### General

#### 1.1 Scope

- 1.1.1 These Guidelines are applicable to non-self propelled units which are mounted with nuclear reactors onboard for power generation and moored at a fixed site. These are referred to in these guidelines as floating nuclear power plants (FNPPs). A schematic of a FNPP is shown in figure 1.1.1.

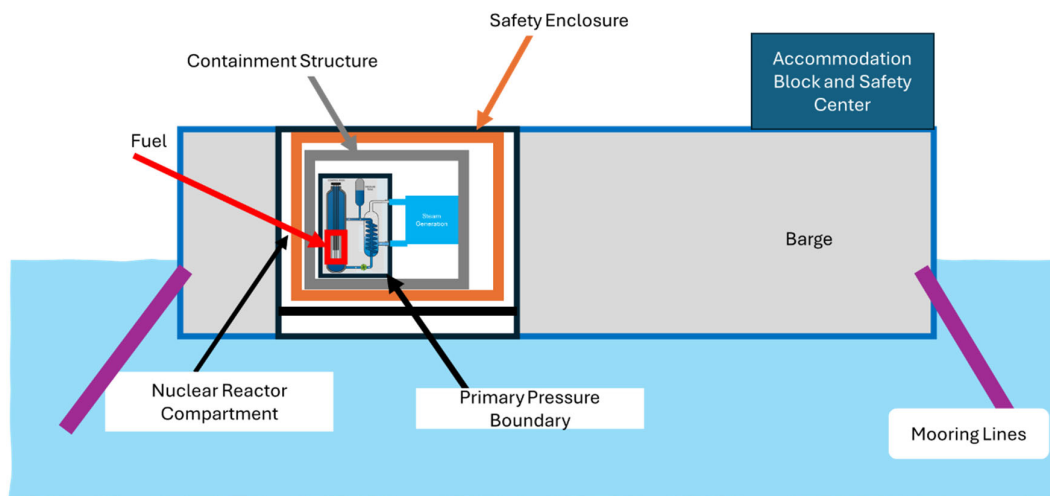


Figure 1.1.1: Schematic (plan) of a FNPP

- 1.1.2 The Guidelines specify the requirements for FNPPs with regard to their design, construction, testing, installation, commissioning and periodical surveys.
- 1.1.3 Unless otherwise specified, the requirements in *IRS Rules and Regulations for Construction and Classification of Steel Ships* (hereinafter referred to as “Main Rules”) are applicable. In the event of a conflict between the requirements of Main Rules and these Guidelines, the requirements provided in the Guidelines are applicable.
- 1.1.4 It is recognized that nuclear technology, especially non-water-cooled reactor designs, are in an evolutionary phase while certain technologies are at an advanced design stage. This document is developed using IMO resolution A.491(XII) as the basic framework. It may be noted A.491(XII) was developed considering pressurized water-cooled reactors. It is not the intention of these Guidelines to discourage applications of non-water-cooled reactor technology, while also acknowledging the need for pragmatism considering their novel nature. For those instances where requirements in this document may preclude or may not be feasible for such applications, such instances should be further discussed with IRS. In this regard, reference is made to the *IRS Guidelines on Alternative and/or Risk Based Design Evaluation*.

#### 1.2 Classification

- 1.2.1 The scope of classification covers the following:

- Hull of the FNPP
- Machinery of the FNPP which is essential for it's safe operation but which is however not directly used for safety and function of the nuclear power plant (NPP) onboard
- Mooring system for position keeping of the FNPP including attachments to the FNPP Hull

- Electrical, Control and Safety Systems of the FNPP which are essential for its safety but however not directly used for safety and function of the nuclear power plant onboard
  - Interfaces between the FNPP Hull and the Nuclear Power Plant installed onboard
- 1.2.2 The Classification of a FNPP is subject to the nuclear reactor(s) installed on board being licensed by the relevant National Nuclear Regulatory Body (refer section 1.3). It is the responsibility of the owner/operator to ensure that such licenses are obtained from the National Nuclear Regulatory Body as well as their validity is maintained in compliance with the applicable national and coastal state regulations.
- 1.2.3 Floating Nuclear Power Plants in compliance with these Guidelines may be assigned the “FNPP” class notation. Additionally, they may be assigned additional notations such as:
- service restrictions or site(s) restriction(s)
  - mooring system (“**Nearshore Mooring**”, or “**Moored in Sheltered Waters**” or “**Deep Water Mooring**”)

A class notation for FNPP would appear as shown below:

☞ **SUL FNPP, Moored in Sheltered Waters**

### **1.3 Interface between Classification Aspects and Nuclear Safety Aspects**

- 1.3.1 The design, construction, installation, commissioning and periodical surveys/ inspections of each nuclear power plant should comply with the requirements of the National Nuclear Regulatory Body. Each nuclear power plant installed on an FNPP should be licensed by the National Nuclear Regulatory Body in accordance with the national regulations and international regulations (as relevant and applicable).
- 1.3.2 A copy of the documentation submitted to the National Nuclear Regulatory Body for securing licensing of the nuclear power plant along with the safety assessment report(s) by the National Nuclear Regulatory Body which are relevant for the classification aspects should be submitted to IRS for information and reference.
- 1.3.3 All boundary conditions (e.g. motions and accelerations of the FNPP) and interfaces between the FNPP Hull and nuclear power plant considered during the licensing process should be identified and submitted to IRS for review in a “Boundary Conditions” document. The specifications of boundary conditions and interfaces would be subject to consideration by IRS and the statutory authorities.
- 1.3.4 The Boundary Conditions document should clearly document the responsibilities of IRS and the National Nuclear Regulatory Body with regard to the interfaces identified to be addressed.
- 1.3.5 Unless specified otherwise, the requirements in these Guidelines should be considered for inclusion in the Boundary Conditions document.
- 1.3.6 Where stricter requirements may be imposed by the statutory authorities, then those requirements will prevail over those provided in these Guidelines.

### **1.4 Safety Concept, Objectives and Principles**

- 1.4.1 The following are the general safety objectives which should be complied with by the design, construction and installation of the FNPP at a given site.
- .1 The overall safety of the nuclear power plant is the primary objective. This includes the safety of the nuclear reactor and the safety of the FNPP which is an integral part of overall safety.
  - .2 People and the environment should be protected from the harmful effects of ionising radiation that could arise from the operation of a nuclear reactor. This has to be achieved without unduly limiting the operation of the nuclear reactor.

- .3 Installation of nuclear reactor on FNPP should ensure that the following are complied with:
  - a. prevent persons from exposure to radiation emanating from nuclear reactor and its auxiliary systems including the spent fuel storage
  - b. minimize the likelihood of events that might lead to a loss of control of the nuclear reactor
  - c. prevent the release of radioactive material to the environment
  - d. minimize the radiation exposure of people and the release of radioactive material to the environment in case of loss of containment
  - e. mitigate the consequences of loss of containment if they were to occur.
- .4 Radiological risks including those risks arising from concentrated energy sources, such as high pressure and high temperature fluids, should be minimized by appropriate means to prevent the occurrence of accidents and the severity of their effects.

1.4.2 A Safety Assessment is to be performed. The Safety Assessment should recognize other hazards which could affect the FNPP taking into account national/ international regulations.

1.4.3 The design of the nuclear reactor should incorporate defense in depth so that there are several levels of defense provided that are aimed at preventing the occurrence of accidents and mitigating the consequences of accidents if they do occur.

- .1 The first level of defence is to prevent deviations from normal operation and the failure of items important to safety. This requires that the nuclear reactor is soundly designed, constructed, maintained and operated in accordance with quality management and design practices.
- .2 The second level of defence is to detect and control deviations from normal operation to prevent anticipated operational occurrences from escalating to accident conditions.
- .3 The third level of defence is to incorporate safety systems in the design of the nuclear reactor to provide protection for the accidents that could occur.
- .4 The fourth level of defence is to mitigate the consequences of accidents that occur following the failure of the safety systems included in the third level of defence. This is achieved by preventing the progression of such accidents and mitigating the consequences of a severe accident
- .5 The fifth level of defence is to mitigate the radiological consequences of the release of radioactive material that could occur following a severe accident. This requires that emergency response facilities are set up and emergency plans and procedures are developed.

Note: The above principles for defence in depth are applicable to conventional nuclear reactors (i.e. pressurized water reactors). For small modular reactors, these will have to be specially adapted. Please see document INSAG 28 by the International Nuclear Safety Advisory Group “*Application of the principle of defence in depth in Nuclear Safety to Small Modular Reactors – Addendum to INSAG-10*”

1.4.4 As part of the application of defence in depth, the design of the nuclear reactor should include multiple physical barriers to the release of radioactive material from the reactor core to the environment following any Initiating Event. The barriers should include the following as a minimum:

- .1 Primary Barrier to contain the nuclear fuel and radioactive material produced in the nuclear reactor core.
- .2 Secondary Barrier to contain the reactor core and the primary coolant (i.e. the reactor vessel and the primary pressure boundary).
- .3 Tertiary Barrier in form of a Containment Structure which surrounds the secondary barrier and confines any leakages from it following any accident sequence.
- .4 Quaternary Barrier in form of a Safety Enclosure which surrounds the containment structure and confines any leakages from it following any accident sequence.

1.4.5 The design of structures, systems and components should include adequate safety margins so that they are able to perform their safety functions throughout their design life. The safety margins should take into account wear and ageing.

1.4.6 The Safety Assessment should demonstrate that justified margins have been included in the design of the FNPP to take account of uncertainties and to avoid cliff edge effects.

1.4.7 The design of the nuclear reactor should include measures for radiation protection to ensure that the radiological doses to the plant operators, other members of the crew and the public are within the defined dose limits and as low as reasonably achievable (ALARA), economic and social factors being taken into account. The radiation protection measures should include the following but not be limited to:

- .1 Providing adequate shielding around sources of ionising radiation.
- .2 Establishing controlled areas to ensure that access of operating personnel to areas with radiation hazards is adequately controlled.
- .3 Dividing the plant into zones that take account of the expected radiation level.

Note: The above measures consider design aspects. There may also be other operational measures (e.g. limiting exposure times for persons). However, these are not considered to be a part of Classification.

1.4.8 The design process should include a systematic consideration of human factors and the human-machine interfaces to facilitate smooth interaction between the operating personnel and the plant, in all Plant States.

1.4.9 The need for intervention by the operator on a short time scale should be kept to a minimum, and it shall be demonstrated that the operator has sufficient time to make a decision and to act.

1.4.10 The nuclear reactor should be designed, constructed, tested, inspected, operated and decommissioned under a Quality Assurance Programme (QAP) (please see A.491(XII), Appendix 5).

1.4.11 For FNPPs, the Safety management Systems (SMS) onboard should be complemented by a Quality Management System (QMS) that is defined and carried out for the design, manufacture, commissioning, operation and decommissioning of a nuclear reactor. This should include provisions for ensuring the quality of the design of all the structures, systems and components in each of the safety classes, as well as of the overall design of the nuclear reactor, at all times.

1.4.12 This should include the means for identifying and correcting design deficiencies, for checking the adequacy of the design and for controlling design changes.

1.4.13 The QMS requirements should be applied to structures, systems and components assigned to each of the safety classes.

1.4.14 The extent to which the individual requirements should apply should follow the graded approach and will depend upon:

- .1 safety classification of the item.
- .2 The need for special controls, administrative measures and surveillance over processes, methods and equipment.
- .3 The degree to which compliance with design requirements can be demonstrated by inspection or test.
- .4 The quality, history and degree of standardization of the item.

- .5 The accessibility, including both physical and environmental consideration, of the component after installation in the plant for maintenance, in-service inspection and replacement.

Note: 1.4.11 – 1.4.14 do not constitute Classification requirements but are nevertheless listed for the attention of the stakeholders involved keeping in view that robust design should be complemented by safe and efficient operation.

1.4.15 The design of a nuclear reactor should ensure that radiation doses to workers at the plant and to members of the public do not exceed the dose limits, that they are kept as low as reasonably achievable in operational states for the entire lifetime of the plant, and that they remain below acceptable limits and as low as reasonably achievable in, and following, accident conditions.

1.4.16 As a general principle governing the acceptability of accident risks, the probability of occurrence of accident situations should be minimized. In assessing accident situations, possible interactions between the NPP, the FNPP hull and machinery and its intended service should be considered.

1.4.17 All the safety and protection systems provided for the nuclear reactor including the primary pressure boundary should meet the single failure criterion (please refer appendix 6 of A.491(XII)).

1.4.18 Where a high reliability is required for those nuclear safety systems that carry out fundamental safety functions and their support systems, the design of the safety systems should incorporate:

- .1 Redundancy - which refers to the replication of systems or components to provide excess capability for fulfilling an essential function so that the fundamental safety functions can be fulfilled following a single failure.
- .2 Independence - which requires that the functioning of one system does not rely in any way upon the functioning of another given system.
- .3 Segregation - which means the physical separation of systems performing a common function to reduce the probability of concurrent loss from a common external cause.
- .4 Diversity - which means the protection of systems and components performing the same task from common cause failure (CCF), by having them differ from each other as regards design, operation, manufacturer, etc.

1.4.19 Nuclear Power Plant States (hereafter referred to as “Plant States”) which are required to be considered in the design of the nuclear reactor should be classified according to their likelihood of occurrence, which may range from continuous to extremely remote. For each class of occurrence frequency, a consequence limit should be assigned as shown below.

<b>Plant State</b>	<b>Description</b>	<b>Frequency</b>	<b>Consequence Class</b>
1	Normal Operation	Continuous or frequent	1
2	Anticipated Operational Occurrences	Infrequent	2
3	Design Basis Accidents	Remote	3
4	Design Extension Condition	Extremely Remote	4

1.4.20 The Design Extension Conditions should be normally subdivided into states where core damage has or has not occurred and where sources of electrical power and cooling are or are not available.

1.4.21 The frequency classification of the Plant States should correspond typically to the following qualitative descriptions:

- .1 Continuous or frequent: this relates to normal operation which is operation within specified operational limits and conditions. This Plant State occurs continuously or is likely to occur often during the service life of a nuclear reactor and includes start-up, power operation, shutdown, maintenance and testing

- .2 Infrequent: this relates to anticipated operational occurrences which are deviations of an operational process from normal operation that is expected to occur at least once during the operating lifetime of a facility but which, in view of appropriate design provisions, does not cause any significant damage to items important to safety or lead to accident conditions
- .3 Remote: this relates to design basis accidents which are postulated accident leading to accident conditions for which a facility is designed in accordance with established design criteria and conservative methodology, and for which releases of radioactive material are kept within acceptable limits
- .4 Extremely remote: this relates to Beyond Design Basis Accidents which are postulated accident conditions more severe than those of a design basis accident and Design Extension Conditions which are postulated accident conditions that are not considered for design basis accidents, but that are considered in the design process of the facility in accordance with best estimate methodology, and for which releases of radioactive material are kept within acceptable limits. The frequency of Postulated Initiating Events in this class is extremely low but they are nevertheless possible

1.4.22 Consequences for each class of Plant State are typically defined as follows:

- .1 Class 1 consequences: the nuclear reactor(s) continue to operate within the radiological limits for normal operation
- .2 Class 2 consequences: those which arise from unplanned occurrences without disturbing significantly the operation of the nuclear reactor and which do not result in a dose equivalent in excess of the relevant dose-equivalent limit for occupationally exposed persons, measured at locations specified by statutory authorities.
- .3 Class 3 consequences: those that may involve a limited unavailability of nuclear reactor(s), either singly or in combination; a degradation of the ship's structure, the nuclear reactor or the safety systems; injuries; the need for external assistance; but do not result in a radiation dose in excess of the relevant dose-equivalent limit for occupationally exposed persons as measured at locations specified by statutory authorities.
- .4 Class 4 consequences; those that may ultimately involve, either singly or in combination, loss of life or loss of the nuclear reactor but do not result in a dose equivalent in excess of the relevant dose-equivalent limit for occupationally exposed persons as measured at locations specified by statutory authorities.

1.4.23 The justification for the frequency class to which each Postulated Initiating Event has been assigned should be provided in the Safety Assessment Report and supported by objective evidence.

1.4.24 Analysis should be carried out to determine the consequences of each Postulated Initiating Event identified. The level of detail of the analysis should be consistent with the graded approach.

1.4.25 The design of the nuclear reactor should be appropriate so as to facilitate its safe decommissioning with minimal impact on workers or the environment.

1.4.26 The Safety Assessment should take account of the factors that affect the radiological consequences which would include the power level at which the nuclear reactor was operating beforehand, the various transients affecting it during the sinking process, and the final position of the wreck. The Safety Assessment should take into consideration the following but not be limited to:

- .1 The continued supply of power and coolant, etc., to the nuclear reactor
- .2 The possibility of operating control and safety equipment

## 1.5 Documentation and Drawings

- 1.5.1 Design basis document(s) should be submitted illustrating the various systems and their operating envelopes on the FNPP.
- 1.5.2 For the FNPP hull, plans and documentation should be submitted in accordance with the Main Rules, Part 3, Chapter 1, Section 3.
- 1.5.3 For the FNPP mooring system, plans and documentation should be submitted in accordance with the list given below (as relevant and applicable).
- Environmental data (wind, waves, current) for site (for review)
  - Geotechnical data for the seabed including reports and details of field and laboratory tests carried out
  - Detailed mooring lines layout (inclusive of mooring fittings such as fairleads, stoppers, accessories etc.)
  - Mooring analysis calculations/report
  - Motion analysis/report of the FNPP considered for the mooring analysis calculations listed above.
  - Mooring model tests
  - Calculations for the foundations/anchor holding capacities. In addition, or in lieu, field test data may also be submitted.
  - Specifications which may include test data for the materials of wire ropes, cables, chains, anchors, fairleads, stoppers and other miscellaneous accessories.
  - Corrosion protection plan
  - Alarms and monitoring systems for tensions in the mooring lines
  - Alarms and monitoring systems for FNPP motions and excursions
  - Survey and Inspection plan
- 1.5.4 For the Licensed Nuclear Power Plant installed onboard, the following approved documentation and drawings should be submitted for information to IRS:
- Arrangements of the Nuclear Reactor System Compartments
  - Arrangements of the Nuclear Reactor Systems
  - Arrangement of the Nuclear Steam Supply System(s)
  - Arrangement of the radiological shielding
  - Safety Assessment Report
    - General Considerations
      - Scope of the Safety Assessment
      - High level description of the design and operation of the FNPP, the way that the electrical power is produced by the nuclear power plant, and the overall layout of the FNPP including the nuclear power plant.
      - Expected modes of operation of the FNPP which typically include operation at full power, operation at reduced power etc.
      - demonstrating that the FNPP is safe to address the application of the high-level safety requirements such as defence in depth, the incorporation of multiple barriers to the release of radioactive material and the incorporation of wide safety margins
      - Applicable regulations, codes, standards and regulatory requirements that are applicable to the FNPP and how compliance with these will be demonstrated
    - Operating environment
      - Operating environment for the FNPP which includes the on-site, transit operations and dry-dock operations
      - Human induced hazards that could for near shore FNPPs from industrial activities in the vicinity
      - Human induced hazards that could arise for FNPP at site including collision and sinking

- Natural hazards that include extreme conditions for waves, wind and tsunami.
- Design Basis Accidents that are used in the design of the FNPP
- Conditions in the operating environment that influence the feasibility of carrying out the emergency plan following a nuclear accident.
- Safety objectives and design rules for structures, systems and components (SSC)
  - Safety objectives and design principles applicable to nuclear safety related structures, systems and components
  - Safety classification of structures, systems and components, the equipment qualification and the in-service monitoring, tests, maintenance and inspections
  - Protection provided against internal and external hazards
  - General design aspects of the FNPP, the nuclear reactor plant, mechanical systems and components, instrumentation and control systems and electrical systems
- Nuclear Reactor
  - Design of the nuclear reactor plant including the fuel design, nuclear design and thermohydraulic design
  - Design of the reactor control, shutdown and core monitoring systems
- Reactor coolant system and associated systems
  - Design of the reactor coolant system including the reactor coolant system, the reactor vessel and coolant circulation
  - Safety design basis for the reactor coolant system and the connected systems
  - Removal of heat generated from the reactor core
  - Design of the reactor auxiliary systems including the primary circuit clean-up system and the residual heat removal system
- Engineered safety features
  - Design of the systems that are incorporated in the design to keep the reactor safe in normal operation and in accident conditions
  - Design of the systems to control the reactivity to shut the reactor down and maintain it in a shutdown state in accident conditions.
  - Design of the systems to remove decay heat from the reactor after shutdown including the emergency core cooling system, the residual heat removal system and the associated heat removal support systems
  - Design of the containment structure, the safety enclosure, the reactor compartment and the associated containment support systems
- Instrumentation and control
  - Design of the instrumentation and control systems, the overall architecture and the functional allocation
  - Design of the reactor control systems, the reactor protection system and the actuation systems for the engineered safety features during normal operation and in accident conditions
- Electrical power
  - Design of the electrical power system for the power generated by the nuclear reactor plant, any standby systems that would be used to provide power when the plant was not operating and any standby power systems such as diesel generators and batteries
- FNPP structures
  - Design of the FNPP including the containment structures and the collision protection structures
- Power conversion systems
  - Description of the design of the systems that remove heat from the reactor core which is used to generate electrical power
- Management of radioactive waste
  - Design of the systems incorporated in the design to remove radioactive material from the coolant systems (FNPP)

- Design of the systems used to handle, condition, store and discharge solid, liquid and gaseous radioactive waste generated during the operation of the FNPP and during decommissioning
- Design of the facilities for the storage of new and irradiated fuel and to refuel the reactor
- Radiation protection
  - Identification of the sources of radiation in the FNPP
  - Design features incorporated to provide radiation protection including the choice of materials, shielding and HVAC systems
  - Identification of the applicable dose limits and targets and the demonstration that the As Low as Reasonably Achievable (ALARA) requirement has been met.
  - Design of the radiation protection facilities which include radiation shielding, monitoring and access control
- Operations (for information and reference)
  - Organization structure, qualifications and training of the nuclear plant operators and other crew members on the FNPP
  - Plant procedures and guidelines for the operation of the FNPP
  - Nuclear safety and nuclear security interfaces
- Safety Evaluation
  - Description of the deterministic and probabilistic analysis that has been carried out to demonstrate the safety of the design and operation of the FNPP. This should be carried out during the design process so that the insights from the analysis could be fed back to improve the design
  - Identification, categorization and grouping of a comprehensive list of Postulated Initiating Events (PIE) and accident conditions to include internal initiating events and internal and external hazards
  - Definition of the safety objectives and acceptance criteria for the deterministic and probabilistic safety analysis
  - Inclusion of human actions in the deterministic and probabilistic safety analysis
  - Deterministic safety analysis of normal operation, anticipated operational occurrences, design basis accidents, design extension conditions and severe accidents (deterministic safety analysis should include the analysis of the thermal-hydraulic behaviour of the nuclear reactor plant core and the cooling systems following a PIE. The analysis would normally assume that the PIE occurred at the worst time in the operation of the FNPP and that the worst single failure occurred in the safety systems that were required to operate following the PIE)
  - Probabilistic Safety Analysis (PSA) to include Level 1 and Level 2 PSA, insights from the PSA and PSA applications (The Probabilistic Safety Analysis (PSA) should determine the risk to the public arising from the operation of the FNPP . The results of the analysis should be compared against the radiological safety criteria defined for the FNPP)
- Operational limits and conditions for safe operation
  - define the safe operating envelope of the reactor plant that ensures that the safety requirements for the risks to nuclear power plant workers and members of the public are met
  - describe the approach to managing nuclear safety, the plant management processes, the monitoring and reviewing of safety performance, and the way that this is integrated into the FNPP's manning arrangements.
- Human factors engineering
  - describe the organization of the plant staff in ensuring nuclear safety.
  - Human factors engineering analysis including function analysis and functional allocation, task analysis and the modelling of important human action in the deterministic and probabilistic safety analysis

- Design of the human-machine interfaces for the FNPP and the procedures for normal operation, accident conditions and severe accident management including the main control room, the supplementary control room and other local control positions
- Emergency preparedness and response
  - Description of the arrangements and facilities for carrying out emergency arrangements in the event of a nuclear accident to protect the nuclear plant operators, other crew members and members of the public
- Environmental aspects
  - Environment impact arising from the construction, normal operation, accident conditions and decommissioning of the FNPP
  - Radiological impact to the environment due to the releases of radioactive material during normal operation and following accidents
- Decommissioning and end of life aspects
  - Proposed approach to decommissioning the FNPP at the end of service life
- Evaluation report by the National Nuclear Regulatory Body
- Quality assurance programme developed in accordance with Appendix 5 of A.491(XII)

## 1.6 Definitions

1.6.1: Abnormal Operation: Please refer *anticipated operational occurrences and plant states*.

1.6.2: Accident Conditions: Any unintended event or sequence of events that has/ have the potential to challenge nuclear safety, lead to release of radioactive material from its normal place of residence and a radiological exposure of greater than 0.1 mSv to a member of the crew or greater than 0.01 mSv to a member of the public.

1.6.3 Active Component: A component whose functioning depends on an external input, such as actuation, mechanical movement, or supply of power, and which therefore influences system processes in an active manner. (Examples of active components are pumps, fans, relays and transistors. It is emphasized that this definition is necessarily general in nature as is the corresponding definition of passive components. Certain components, such as rupture discs, non-return valves, safety valves, injectors and some solid-state electronic devices have characteristics which require special consideration before designation as an active or passive component)

1.6.4: Anticipated Operational Occurrences: A deviation of an operational process from normal operation that is expected to occur at least once during the operating lifetime of a facility but which, in view of appropriate design provisions, does not cause any significant damage to items important to safety or lead to accident conditions.

1.6.5: As low as reasonably achievable (ALARA): The process of determining what level of protection and safety would result in the magnitude of individual doses, the number of individuals (workers and members of the public) subject to exposure and the likelihood of exposure being as low as reasonably achievable, economic and social factors being taken into account.

1.6.6: As low as reasonably practicable (ALARP): The process of reducing the risk to a low level where it is possible to demonstrate that the cost involved in reducing the risk further would be grossly disproportionate to the benefit gained.

1.6.7 Beyond Design Basis Accident: Postulated accident with accident conditions more severe than those of a design basis accident

1.6.8 Common Cause Failure (CCF): The failure of a number of redundant devices or components to continue to perform their functions as a result of a single specific event or cause.

1.6.9: Commissioning: A phase following construction during which the FNPP are made operational and are verified to be in accordance with design requirements and to have met required performance criteria. It includes tests of nuclear and non-nuclear systems and culminates with the issue of the Class Certificate and the authorization to operate the FNPP.

1.6.10: Collision Protective Structure: Special protective structure that surrounds the reactor compartment that provides protection for the nuclear power plant and its safety systems, including radioactive waste storage as necessary, against the effects of collision of FNPP with other mobile or immobile objects.

1.6.11: Containment Structure: The leak tight structure that surrounds the nuclear reactor and is designed to contain any leakages of radioactive material from the primary circuit of the nuclear power plant.

Note: This requirement should be specially considered for non-water cooled and small modular reactors

1.6.12: Controlled Area: A Defined area in which specific protection measures and safety provisions are or could be required for controlling exposures or preventing the spread of contamination in normal working conditions and preventing or limiting the extent of potential exposures. The dose equivalent limits in the controlled areas will be defined in line with ICRP guidance.

1.6.13 Criticality: The state of a nuclear chain reacting medium when the chain reaction is just self-sustaining (or critical), i.e. when the reactivity is zero.

1.6.14: Defense in depth: The incorporation of successive levels of defence to protect workers and members of the public from the harmful effects of ionising radiation due to the release of radioactive material from the nuclear reactor.

There are five levels of defense in depth:

- .1 Level 1 – robust design.
- .2 Level 2 – detection of abnormal operational occurrences and return of the reactor to within normal operating limits
- .3 Level 3 – Detection of initiating events and the operation of protection systems to mitigate its consequences
- .4 Level 4 – Operation of specific equipment to provide protection against severe accidents where core damage has occurred
- .5 Level 5 – Offsite emergency actions such as sheltering and evacuation to protect members of the public following a release of radioactive material

This provides successive barriers to the release of radioactive material. Please also refer the note to 1.4.3.

1.6.15: Design Basis: The range of conditions and events that need to be explicitly taken into account in the design of the FNPP such that it can withstand them without exceeding authorized limits by the planned operation of safety systems.

1.6.16: Design Basis Accident: A postulated accident leading to accident conditions for which FNPP is designed in accordance with established design criteria and conservative methodology, and for which releases of radioactive material are kept within acceptable limits.

1.6.17: Design Extension Conditions: Accident conditions that are not considered for design basis accidents, but that are considered in the design process of the FNPP in accordance with best estimate methodology, and for which releases of radioactive material are kept within acceptable limits.

1.6.18: Deterministic Safety Analysis: The analysis of design basis accidents and accident sequences. This is done using conservative assumptions. The results of the analysis are compared to plant limiting values.

1.6.19: Deviation: A departure from specified requirements

1.6.20: Diversity: The presence of two or more systems or components to perform an identified function, where the systems or components have different attributes so as to reduce the possibility of common cause failure.

1.6.21: Dose Equivalent: Quantity expressing the absorbed dose weighted by the quality, distribution and other relevant factors. The purpose of the dose equivalent is to estimate the effects of radiation doses received by persons. The unit of dose equivalent is the sievert (Sv) as defined by the ICRU.

1.6.22: Dose Equivalent Limits: The annual limits on dose equivalent from ionizing radiation recommended by ICRP for occupationally exposed persons.

1.6.23: Emergency Control Position: A location on the FNPP from which complete or partial control of systems or components essential to nuclear power plant safety may be exercised, if control from the main control position is precluded.

1.6.24: Fail Safe System: A system which has moving parts and which is designed to revert to a given state, automatically and without needing either external power nor actuation, in case the operating signal becomes unavailable.

1.6.25: Habitability: Those environmental conditions (e.g. space, temperature, humidity, radiation etc.) which are necessary to allow the continuous stay of the personnel for a given period of time.

1.6.26: Initiating Event: An identified event taken into account in the safety assessment that leads to an anticipated operational occurrence or an accident condition. The primary causes of initiating events are credible failures of structures, systems or components and operator errors. This includes internal faults and hazards, natural external events and human induced external events. This is the starting point for the accident sequences that are addressed in the safety assessment.

1.6.27: ICRP: International Commission on Radiological Protection

1.6.28 Loss of Coolant Accident (LOCA): A postulated accident that results in loss of reactor coolant at a rate exceeding normal make-up capability.

Note: This requirement should be specially considered for non-water cooled and small modular reactors

1.6.29 Normal Operation: Operation of the nuclear power plant onboard FNPP within specified operational limits and conditions. This includes the conditions when all the structures, systems and components can perform their safety related functions within the specified operating limits and conditions. This covers reactor start-up, power operation, shutdown, maintenance, surveys, testing and refuelling. This also includes the minor deviations from desired operating conditions/ Anticipated Operational Occurrences that have been justified in the safety case.

1.6.30 Nuclear Power Conversion System (NPCS): The system of a nuclear power plant which is fitted to convert the heat generated by the reactor into mechanical or electric power.

1.6.31 Nuclear Power Plant (NPP): The nuclear power generation system fitted onboard FNPP, including the nuclear power conversion system (NPCS).

1.6.32 Occupational Exposure: Exposure of workers to radiation released from nuclear fission process incurred in the course of their work.

1.6.33: Passive Component: A component which has no moving part and only experiences such changes as changes in pressure, in temperature or in fluid flow in performing its functions. In addition, certain components which function with very high reliability based on irreversible action or change, may be assigned to this category. (Examples of passive components are heat exchangers, pipes, vessels, electrical cables and structures. It is emphasized that this definition is necessarily general in nature as is the corresponding definition of active components. Certain components, such as rupture discs, check valves, safety valves, injectors and some solid-state electronic devices, have characteristics which require special consideration before designation as an active or passive component).

1.6.34: Plant State: States that are encountered for the onboard nuclear power plant which includes normal operation, anticipated operational occurrences, design basis accidents, design extension conditions and severe accidents.

1.6.35 Postulated Initiating Event: A postulated event identified in design as capable of leading to anticipated operational occurrences or accident conditions. The primary causes of postulated initiating events may be credible equipment failures and operator errors (both within and external to the facility), human induced events or natural events.

1.6.36 Primary Pressure Boundary: That envelope of the nuclear power plant that contains or may contain primary coolant at reactor power operating temperature and pressure.

Note: For non-water cooled and small modular reactors this term will be specially considered by IRS.

1.6.37 Probabilistic Safety Analysis: A structured analysis carried out to identify a comprehensive set of accident sequences that could occur leading to core damage or a radiological risk to workers or members of the public.

1.6.38 Protection System: A system that monitors the operation of the nuclear power plant installed onboard and which, on sensing an abnormal condition, automatically initiates actions to prevent an unsafe or potentially unsafe condition.

1.6.39: Gaseous Radioactive Waste: Any radioactive gas that originates from the NPP or from treatment or storage of radioactive wastes.

Note: This requirement should be specially considered for non-water cooled and small modular reactors

1.6.40: Liquid Radioactive Waste: Any radioactive liquid that originates from the NPP, from treatment or storage of radioactive wastes or from decontamination.

Note: This requirement should be specially considered for non-water cooled and small modular reactors

1.6.41: Solid Radioactive Waste: Any radioactive solid that originates from the NPP, from treatment or storage of radioactive wastes or from decontamination.

Note: This requirement should be specially considered for non-water cooled and small modular reactors

1.6.42: Reactor Compartment: That compartment of the FNPP containing the nuclear power plant bounded by the hull, the bulkhead deck and fore and aft by athwartship cofferdams or bulkheads.

1.6.43: Reactor Control Room: An enclosed space in the FNPP from which the nuclear reactor can be operated safely during normal operation, abnormal operational occurrences and in accident conditions. This includes the facilities for carrying out actions either automatically or manually to carry out the main safety function of control or reactivity, removal of reactor heat and confinement of radioactive material.

Note: This requirement should be specially considered for non-water cooled and small modular reactors

1.6.44: Reactor Vessel: The vessel that contains the reactor fuel and the primary coolant. The type of the vessel depends on the type of the reactor, fuel and coolant. This includes reactors that are water cooled, gas cooled and liquid metal cooled and are at high pressure or atmospheric pressure.

Note: This requirement should be specially considered for non-water cooled and small modular reactors

1.6.45: Relief Valve: A valve actuated manually or automatically that is designed to control the pressure in a system to keep it within acceptable limits.

1.6.46: Redundancy: Incorporation of identical structures, systems or components to perform the same safety function. This prevents a single failure leading to the loss of the safety function following an initiating event.

1.6.47: Residual Heat: The sum of the heat originating from decay (radioactive decay and shutdown fissions) and the heat stored in reactor related structures and in heat transport media.

1.6.48: Safety Assessment: A systematic assessment of all aspects of the design and operation of the FNPP that relate to safety.

1.6.49: Safety Classification: A ranking of structures, systems and components according to their importance for nuclear and marine safety. This importance is evaluated in the light of the consequences of loss of the function performed by these items of plant and equipment in the various foreseeable situations.

1.6.50: Safety Enclosure: A gas and leak-tight enclosure which surrounds the containment structure and any significant source of radioactivity associated with the NPP and the nuclear reactor plant. Its function is to prevent and control the leakage of radioactive material to the environment external to the enclosure.

Note: This requirement should be specially considered for non-water cooled and small modular reactors

1.6.51: Safety Function: A specific function/action that needs to be carried out to ensure the safety of the FNPP and to prevent or to mitigate radiological consequences of normal operation, anticipated operational occurrences and accident conditions. For the nuclear reactor plant the safety functions are:

- .1 Shutdown and hold down of the reactor
- .2 Removal of the residual decay heat
- .3 Confinement of radioactive material.

1.6.52: Safety System: A system important to safety, provided to ensure, in any Plant State, the safe shutdown of the reactor, the residual heat removal from the reactor core, or to limit the consequences of anticipated operational occurrences and design basis accidents.

1.6.53: Safety Valve: An automatic pressure relieving device actuated by the static pressure upstream of the valve and characterized by rapid full opening so as to limit the pressure.

1.6.54: Severe Accident: Accident more severe than a design basis accident and involving significant core degradation.

1.6.55: Shielding: A structure placed round a source of radioactive material to reduce the radiation dose rate in the vicinity below specified levels.

1.6.56: Shutdown: The procedure of rendering a reactor subcritical or the state of a reactor in a subcritical condition.

1.6.57: Sievert: The SI unit of equivalent dose, effective dose and operational dose quantities for measuring ionizing radiation. The unit is joule per kilogram of tissue (J/kg).

1.6.58: Single Failure: A failure which results in the loss of capability of a single system or component to perform its intended safety function(s), and any consequential failure(s) which result from it.

1.6.59: Single Failure Criterion: A requirement applied to a safety system such that it must be capable of performing its safety function in the presence of any single failure.

1.6.60: Supervised Area: A defined area not designated as a controlled area but for which occupational exposure conditions (Exposure of workers incurred in the course of their work) are kept under review, even though specific protection measures or safety provisions are not normally needed.

1.6.61: Ultimate Heat Sink: The atmosphere or a body of water to which heat is transferred during normal operation, anticipated operational occurrences or accident conditions.

1.6.62: Uncontrolled Area: Any area and/or space on the FNPP which is not a controlled or supervised area and/or space for the purposes of protection against ionizing radiation.

1.6.63: Volumetric Examination: A procedure for investigating the complete body volume of a component for flaws and cracks by non-destructive methods, such as ultrasonic inspection, radiography or other appropriate means.

## Section 2

### Risk Assessment

#### 2.1 Objective

- 2.1.1 Risk assessment should be carried out to ensure that the design, arrangement and layout, construction, operations, maintenance and surveys of the FNPP do not pose an unacceptable level of risk to persons, property and environment.

#### 2.2 Risk Assessment

- 2.2.1 The Risk assessment should identify and address major hazard scenarios as outlined below but not limited to:

- Loss of watertight integrity of the FNPP
- Flooding of the nuclear reactor compartment
- Failure of systems for safe containment of spent nuclear fuel
- Structural damage to the FNPP Hull
- Structural damage or loss of the primary containment of the nuclear reactor
- Damage or loss of the interface structures including shielding for protection from nuclear radiation
- Failure or total loss of position keeping (i.e. mooring systems)
- Extreme weather conditions including cyclones and hurricanes
- External Events such as earthquakes and tsunamis
- Fire hazards – Fire in the non-nuclear area affecting the safe operations of the nuclear reactor
- Dropped object from lifting operations which lead to damage of any of the barriers described in 1.4.4
- Loss of coolant accident (LOCA) for the nuclear reactor(s)
- Failure of one or more safety systems and control systems of the nuclear reactor(s)
- Failure of emergency systems for controlling a nuclear incident/accident
- Release of radioactive material as well as unsafe radiation outside the boundaries of the nuclear reactor compartment
- Failure of the primary coolant systems (including their components)
- Failure of the secondary coolant systems (including their components)
- Loss of power supply to the nuclear reactor coolant systems
- Damage or malfunction of the nuclear fuel equipment
- Fire hazards – Fire (nuclear or non-nuclear) affecting the safe operations of the nuclear reactor
- Damage or total loss of the Reactor Control Room and/or the Emergency Control Position
- Maintenance of the Nuclear Reactor including refueling cycles
- Operator errors leading to unsafe scenarios for the nuclear reactor
- Decommissioning of the FNPP

- 2.2.2 It is recommended that a team of experts perform the risk assessment using acceptable methods/techniques. Such experts should be from the following disciplines (indicative):

- Designers, Shipbuilders (Naval Architects & Marine Engineers)
- Ship Operators (e.g. Deck Officers)
- Mooring Systems and Equipment Provider
- Marine Equipment Manufacturers
- Nuclear Technology Provider
- Nuclear Plant Operator(s)
- Nuclear Equipment and Component (including safety and controls) suppliers
- Nuclear Fuel Supplier
- Flag Administration

- National Nuclear Regulatory Body
- National Disaster Management Authority with regard to mitigating effects of a nuclear accident
- Port Authorities (if moored near a port/ shore)
- Class representatives

2.2.3 The Risk assessment should be adequately documented, and the report should include the following but not be limited to:

- Design philosophy of the nuclear power plant including the associated auxiliary systems.
- Composition of the Team of Experts performing the risk assessment along with brief CVs outlining their professional background and experience.
- Details of Hazard Identification Sessions (HAZID).
- Details of simulations or studies performed to address specific scenarios (e.g. gas dispersion analysis)
- Close-out actions identified from the HAZID and Risk Assessment and information on how these are envisaged to be addressed (or aim to be implemented) in the design and construction

2.3 It is recommended to involve IRS at an early stage through the risk assessment process. The final report of the risk assessment should be submitted to IRS for review.

## Section 3

### Hull Structure and Mooring System

#### 3.1 General

3.1.1 All requirements provided in this Section are to be considered as Classification Requirements.

#### 3.2 Hull Structure

- .1 The Hull Structure of the FNPP should be assessed for compliance with the following as applicable: For FNPPs operating nearshore – Parts 2, 3 and 5 of the Main Rules

Note: Nearshore FNPPs are the preferred configuration. A sheltered area preferably protected using breakwaters should be made available for the safe mooring of the FNPP.

- .2 For FNPPs operating at locations which are not near shore and are not ship shaped – Chapters 3 – 9 of the IRS Rules for Construction and Classification of Mobile Offshore Drilling Units

Note: Such FNPPs will be accepted subject to special consideration by IRS.

- .3 For FNPPs operating at locations which are not near shore and are ship shaped – Chapters 3 – 4 of the IRS Rules for Construction and Classification of Floating Offshore Units

Note: Such FNPPs will be accepted subject to special consideration by IRS.

3.2.4 The application of specific Rules as indicated in 3.2.1 should be agreed with IRS. If section 3.2.1.3 is applied, the return period to be selected for evaluation of the hull scantlings should be agreed with IRS.

3.2.5 A longitudinal strength analysis of the FNPP hull should be performed, with due regard to the weight and stiffness characteristics of the nuclear reactor compartment and collision protective structure.

3.2.6 The section modulus in the area of the collision protective structures should not radically change at the end of the structures. This structure should be appropriately integrated into the rest of the FNPP. Structural members at the transition are to be adequately sized and designed to transfer the weight and loads developed in the area of the nuclear reactor compartment and collision protective structure into the rest of the vessel. The transition area should extend as far as necessary forward and aft of the nuclear reactor compartment to provide structural continuity of the hull.

3.2.7 FNPP structures in way of the nuclear reactor compartment should be designed and constructed to give adequate protection to the NPCCS from external forces which are detailed in Section 4.

3.2.8 The foundation structures for the reactor vessel and primary pressure boundaries, containment structure and the safety enclosure should be adequately designed for proper support under the conditions specified in Section 4. They should be adequate to retain the reactor vessel, primary pressure boundaries, containment structure and safety enclosure in position under any inclination. The supports should accommodate all thermal stresses. Accessibility for inspection and maintenance of the containment structure as well as safety enclosure should be provided.

3.2.9 Design of the foundations of the safety enclosure and of the containment structure should account for loads from the hull deformations and the inertial forces.

3.2.10 Nuclear Power Plant Shielding supports should be designed to account for the inertial forces acting on that shielding and due to the deformation of the structure of the FNPP.

3.2.11 Structural interfaces of the barge/ pontoon and the NPP should be verified using finite element analysis. Such analysis should be carried out in accordance with the IRS Guidelines on *Structural Assessment of Ships based on Finite Element Method*.

### **3.3 Subdivision and Stability**

3.3.1 The FNPP should comply with the subdivision and damage stability requirements specified in the Main Rules, as relevant and applicable. The subdivision and stability requirements as provided in Section 3.4 of A.491(XII) should also be complied with.

3.3.2 When collision protective structures are provided and specially designed to limit penetration of FNPP at the location of the Reactor Compartment, IRS may consider a lesser extent of side damage than that given in Section 3.4 of A.491(XII), subject to an equivalent protection against flooding being provided.

3.3.3 If any damage of a lesser extent than specified in 3.3.2 results in a more severe condition, such damage should be assumed.

3.3.4 If pipes, ducts or tunnels are situated within the considered extent of damage, arrangements should be made to ensure that progressive flooding cannot thereby extend to compartments other than those assumed to be floodable for each case of damage.

3.3.5 Stability Information should be kept onboard and include:

- .1 data necessary to maintain sufficient intact stability under service conditions to enable the FNPP to withstand various conditions of damage
- .2 information on damage resistance for the particular FNPP and recommended damage evaluation and damage control actions for each of the different damage conditions
- .3 actual survival capability of the FNPP under more severe damage penetration than required by 3.3.1

### **3.4 Position Keeping and Mooring System**

3.4.1 For position keeping and mooring system of the FNPP, the design, construction, installation and periodic surveys should be in accordance with the following:

- .1 For FNPPs operating nearshore, the IRS *Rules for Construction and Classification of Steel Ships* (to be applied if 3.2.1 is deemed applicable for the Hull Structure)
- .2 For FNPPs operating at locations which are not near shore and are not ship shaped - Chapter 10 of the IRS *Rules for Construction and Classification of Mobile Offshore Drilling Units* (to be applied if 3.2.2 is deemed applicable for the Hull Structure)
- .3 For FNPPs operating at locations which are not nearshore and are ship shaped – Chapter 5 of the IRS *Rules for Construction and Classification of Floating Offshore Units* (to be applied if 3.2.3 is deemed applicable for the Hull Structure)

## Section 4

### Design Criteria and Conditions

#### 4.1 Fundamental Safety Functions

4.1.1 Basic safety functions mentioned as below should be ensured under all conditions for the nuclear reactor power plant.

- .1 Control of reactivity
- .2 Removal of heat from the reactor
- .3 Confinement of radioactive material, shielding against radiation and control of planned radioactive releases.
- .4 Limitation of accidental radioactive releases

4.1.2 The fulfilment of the basic safety functions should be ensured by implementation of measures as listed in this section. It is recognized that requirements in this Section should be evaluated by the national nuclear regulatory authority in consultation with IRS and the flag administration where necessary.

#### 4.1.3 Control of reactivity

4.1.3.1 Means should be provided to ensure that there is capability to safely shut down the reactor in all operational states and in accident conditions, and that the shutdown condition can be maintained even for the most reactive conditions of the reactor core.

4.1.3.2 The effectiveness, speed of action and shutdown margin of the means of shutdown of the reactor should be such that the specified design limits to prevent damage to the reactor core are not exceeded.

4.1.3.3 The shutdown margin should be demonstrated to be adequate even if failures occur that render part of the means of shutdown inoperative.

4.1.3.4 The means for shutting down the reactor should consist of at least two diverse and independent systems.

4.1.3.5 At least one of the two different shutdown systems should be capable, on its own, of maintaining the reactor subcritical by an adequate margin and with high reliability, even for the most reactive conditions of the reactor core.

4.1.3.6 The means of shutdown should be adequate to prevent any foreseeable increase in reactivity leading to unintentionally producing criticality during shutdown.

4.1.3.7 Instrumentation should be provided and tests should be specified for ensuring that the means of shutdown are always in the state stipulated for a given plant state

#### 4.1.4 Removal of heat from the reactor

4.1.4.1 Means should be provided for removing residual heat from the reactor in the shutdown state such that the design limits for the reactor, the coolant boundary and structures important to safety are not exceeded.

4.1.4.2 Means should be provided for restoring and maintaining cooling of the reactor core for a sufficiently long time under potential accident conditions. This time should be assessed within the Risk Assessment in Section 2.

4.1.4.3 Means should be provided for ensuring the capability to transfer heat to an ultimate heat sink for all Plant states.

4.1.5 Confinement of radioactive material, shielding against radiation and control of planned radioactive releases.

4.1.5.1 Means should be provided to ensure that the radioactive doses to operating personnel at the nuclear power plant will be maintained below the dose limits and will be kept as low as reasonably achievable and that the relevant radiation dose constraints will be met.

4.1.5.2 Means should be provided to ensure the integrity of the reactor core, the primary pressure boundary, the containment structure, the safety enclosure and the reactor compartment at all times.

## **4.2 Safety Classification of Structures, Systems and Components (SSC)**

4.2.1 All SSC important to safety should be identified and categorized on the basis of their function and their safety significance. The design should be such as to ensure that any interference between items important to safety will be prevented, and in particular that any failure of items important to safety in a system in a lower safety category (see 4.2.4) will not propagate to a system in a higher safety category.

4.2.2 The identification of the SSC important to safety should take account of the following factors:

- .1 The safety function(s) to be performed by the SSC
- .2 The consequences of failure to perform a safety function
- .3 The frequency with which the SSC will be called upon to perform a safety function
- .4 The time following a postulated initiating event at which, or the period for which the SSC will be called upon to perform a safety function

4.2.3 Three levels of severity should be defined:

- .1 'High' if failure of the function could, at worst, lead to a release of radioactive material that exceeds the acceptable limits or causes the values of key physical parameters to exceed acceptance criteria for design basis accidents
- .2 "Medium' if failure of the function could, at worst, lead to a release of radioactive material that exceeds limits established or leads to values of key physical parameters to exceed the design limits for anticipated operational occurrences
- .3 "Low" if failure of the function could, at worst, lead to doses to workers above authorized limits

4.2.4 The following safety classes for structures, systems and components should be selected:

- .1 Safety class 1: Any SSC whose failure would lead to consequences of 'high' severity
- .2 Safety class 2: Any SSC whose failure would lead to consequences of 'medium' severity
- .3 Safety class 3: Any SSC whose failure would lead to consequences of 'low' severity

4.2.5 The SSCs included in the three Safety Classes should be identified in the safety assessment.

4.2.6 The Safety Class assignments of SSCs should be made on a case by case basis that takes account of the deterministic and probabilistic safety analysis with due account taken of the safety function that they perform, the consequences of failure to perform the safety function, the frequency of

demand that it is called upon to perform the safety function and the time following the postulated initiating event at which, or the period for which, the item will be called upon to perform a safety function. The justification for the safety categorization should be provided in the Safety Assessment for review by IRS and the statutory authorities.

4.2.7 The engineering design standards should be specified for the SSCs in each of the safety categories. These are the relevant national and international codes, standards and proven engineering practices that are applicable to the design of SSCs to meet the applicable design requirements. For SSC which constitute a part of the FNPP Hull Structures, IRS Main Rules are to be de-facto included as an engineering standard.

4.2.8 The set of engineering design standards specified should ensure that the SSCs will be designed, manufactured, constructed, installed, commissioned, operated, tested, inspected and maintained to appropriate quality requirements.

4.2.9 The design standards specified should ensure that appropriate levels of capability to perform the required safety function, reliability so that the associated failure rate is low and robustness so that it will be able to function with the loads imposed in normal operation and following accidents.

4.2.10 The design standards should take account of the loads due to the presence of a marine environment. These may be typically imposed due to vibrations and forces from FNPP motions and accelerations.

### **4.3 Environmental Conditions**

4.3.1 The environmental conditions applicable to the site(s) where the FNPP is to be deployed and the nuclear reactor during service should be identified and taken into account in the design. It should be demonstrated that there is an adequate safety margin against the effects of environmental conditions that could arise.

4.3.2 The Safety Assessment should address the safety of the FNPP including the times when it is in dry-dock and/or Port/Anchorage (as may be necessary for its operations). This needs to take account of the local meteorological conditions, population density and land usage factors.

4.3.3 As required by the various Plant States, design considerations for the FNPP and its nuclear power plant should consider the effects of natural phenomena, such as extraordinary seaways, tsunamis, tornadoes, cyclones, hurricanes, winds, snow and ice as may be applicable.

4.3.4 The inertial forces acting on the FNPP at the deployed site(s) and during all its transport operations should be taken into account in the design for each of the SSCs according to their Safety category. The inertial forces should be evaluated accordingly.

4.3.5 Such analysis should determine the motion of the FNPP in six degrees of freedom, utilizing the wave spectrum for the intended site(s) of operation or, where such wave data are not available, an alternative analysis acceptable to IRS and the flag Administration.

4.3.6 The SSCs should be capable of withstanding the inertial forces according to their Safety Class and commensurate with their safety functions.

4.3.7 The design of the FNPP and its nuclear power plant should take account of shock loads from accidents such as collision, grounding or explosion.

4.3.8 Motions of the FNPP should be taken into account when evaluating the stability of the reactor control and when evaluating the dynamic behaviour of the reactor.

4.3.9 The design of SSCs for the reactor protection and safety systems should withstand the steady or dynamic inclinations that could occur with adjacent compartments flooded, however the FNPP should remain afloat during and after such events.

4.3.10 The reactor safety systems should be designed to operate within the limits of the angles of static list, rolling or inclination specified as below:

- .1 a static list of up to 30° or rolling angles of up to 45°,
- .2 inclined to 10° either in the fore or aft direction,
- .3 or in any combination of angles within those limits, or a single motion, not exceeding 45° to one side.

Alternative proposals for the parameters presented above may be considered subject to adequate technical justification. The adequacy of the reactor safety systems should be confirmed during testing taking the above parameters into consideration.

4.3.11 The air conditioning systems for controlled areas and the electronic equipment of safety systems should be designed to operate in the extreme values of relative humidity.

4.3.12 The effects of oil vapours from machinery, dust, smoke in the event of fire and toxic gases should be taken into account in the design.

4.3.13 The effects of machinery induced vibrations should be taken into account in the design and the testing of monitoring devices and control systems and components.

4.3.14 The Nuclear Reactor should be designed to operate satisfactorily under the conditions, having regard to the environmental conditions given above. The Nuclear Reactor should be designed to limit mechanical and cyclical stresses under the effects of vibration, shock loading and accident conditions.

4.3.15 The design and operation of the Nuclear Reactor should take into account the following but not be limited to:

- .1 The reactor should continue to operate with no automatic reactor trip following any Plant State 1 event (pse see 4.4 for definition of plant states).
- .2 The reactor should be able to be restarted, at reduced power, within a reasonable time period, without reduction in safety following any Plant State 2 event
- .3 The reactor should be able to be shut down and cooled following any Plant State 3 event
- .4 An unacceptable hazard to the public or the environment or a release of radioactive material in excess of the specified limits occurring following any Plant State 3 event
- .5 The radiation doses to the public and members of the crew should be within the dose criteria defined/ recommended by the ICRP and be as low as is reasonably achievable (ALARA).

4.3.16 The Nuclear Reactor(s) should be capable of responding to safety actions at least as rapidly as a conventional steam turbine plant of similar size and power.

4.3.17 The Nuclear Reactor(s) should be capable of being started without external aid to the extent practicable (i.e. "deadship" condition).

4.3.18 Means should be provided to permit adequate testing of reactor safety systems.

4.3.19 Means should be provided to permit adequate testing of the strength of SSCs that are subject to mechanical, thermal or pressure loading.

4.3.20 Adequate protection should be provided against extreme environmental conditions such as those associated with tornadoes, cyclones and hurricanes for the safe operation of the FNPP and the nuclear reactor(s).

4.3.21 Adequate physical protection should be provided to protect the FNPP against malevolent acts including sabotage, theft of radioactive material, hijacking or other criminal acts that affect nuclear safety.

## 4.4 Nuclear Power Plant States

4.4.1 Four categories of Plant States are defined in this sub-section according to their frequency of occurrence and the associated Consequence categories. It should be demonstrated by the Safety Assessment that the frequency and consequence requirements have been met.

4.4.2 **Plant State 1** includes planned or unplanned activities that occur frequently during normal operation such as:

- .1 Start-up, low power, full power operation
- .2 Shutdown
- .3 Operations during rough weather and sea conditions

4.4.3 **Plant State 2** includes Abnormal Operational Occurrences which are unplanned events that occur infrequently during normal operation due to failure or incorrect operation of an active component in the nuclear reactor(s), the power conversion system, the protection systems, the electrical systems, the ultimate heat sink or the support systems.

4.4.4 **Plant State 3** includes unplanned events which are remote such as Design Basis Accidents which are postulated accident leading to accident conditions for which a facility is designed in accordance with established design criteria and conservative methodology, and for which releases of radioactive material are kept within acceptable limits. This includes reactor accidents such as complete failure of reactor heat removal, failure of reactivity control leading to a rapid increase in reactivity, loss of reactor coolant and failure of reactor support systems. It also includes accidents such as an on-board fire or explosion, collision, stranding, grounding, and extreme sea or weather conditions.

4.4.5 **Plant State 4** includes events that are extremely remote such as Beyond Design Basis Accidents and Design Extension Conditions. The frequency of Postulated Initiating Events in this class is extremely low but they are nevertheless possible. This includes accident conditions with and without some source of power being available and with and without reactor core damage.

## 4.5 Safety Assessment

4.5.1 A Safety Assessment should be carried out to determine whether an adequate level of safety has been achieved for the FNPP and whether the applicable safety objectives, principles and requirements have been met.

4.5.2 The Safety Assessment should be carried out at an early stage in the design process for a FNPP and the outcomes from the deterministic and probabilistic analysis carried out should be incorporated into the development of its design and operation.

4.5.3 The Safety Assessment should address the risks due to exposure to nuclear radiation arising in all four Plant States – namely, Normal Operation, Anticipated Operational Occurrences, Design Basis Accidents, Beyond Design Basis Accidents and Design Extension Conditions. This includes internal events occurring inside the FNPP and natural and human induced events occurring outside the FNPP.

4.5.4 The Safety Assessment for Normal Operation, Anticipated Operational Occurrences and Design Basis Accidents should be based on conservative assumptions regarding the magnitude of the Postulated Initiating Event, it occurs at the worst time in the lifetime of the facility and single failures occur in the safety systems that provide protection.

4.5.5 The Safety Assessment for Design Extension Conditions should be based on realistic assumptions and in compliance with statutory requirements.

4.5.6 The Safety Assessment should address the human interactions required with the nuclear reactor during Normal Operation, responding to Anticipated Operational Occurrences and in accident conditions. The Assessment should ensure that no human actions should be required in the short term in any accident situation.

4.5.7 The Safety Assessment should determine whether there is an adequate margin of safety where results of events considered cannot be predicted with certainty.

4.5.8 The Safety Assessment should address the long term consequences of accidents and demonstrate that a safe, stable state has been achieved where the fundamental safety functions are being fulfilled.

4.5.9 The Safety Assessment should also take account of possible combinations of internal and external events and hazards that could affect safety of the FNPP and the nuclear reactor(s).

#### **4.6 Evaluation of Accident Sequences**

4.6.1 The design and operation of the nuclear power plant should take account of accident sequences affecting the FNPP. A systematic analysis should be carried out to identify a comprehensive set of accident sequences which typically includes the following:

- .1 Collision and grounding events which take account of the damage sustained by the FNPP and the flooding of compartments. Collision and grounding events should also be considered which arise from damage to one or more of the mooring lines which lead to loss of position keeping for the FNPP
- .2 Sinking of the FNPP in shallow or deep water which takes account of the flooding of compartments and the containment of radioactive material
- .3 Stranding which takes account of loss of seawater cooling supply where this is used and the different inclinations of the FNPP that could arise
- .4 Loss of position keeping (failure of one or more mooring lines)
- .5 Fire which identifies the possible sources of the fire, fire spread in the FNPP, the action of the fire detection and suppression systems, fire barriers, and damage to the SSCs associated with the nuclear reactor(s).
- .6 Explosion, pressure waves and missiles generated by the failure of pressurised systems or rotating machinery
- .7 Aircraft crash (where this is included as a Design Basis Accident or a Design Extension Condition)
- .8 Smoke and toxic gases originating from inside or outside the FNPP.

4.6.2 Adequate protection should be provided against extreme environmental conditions such as those associated with cyclones, tornadoes and hurricanes for the safe operation of the FNPP.

#### **4.7 Evaluation of Accident affecting safety of the Nuclear Reactor(s)**

4.7.1 A systematic process should be carried out to identify a comprehensive set of Design Basis Accidents, Beyond Design Basis Accidents and Design Extension Conditions that affect the safety of nuclear reactor and need to be addressed in the Safety Assessment. This should typically include the following:

- .1 Increase in reactivity from any initial state
- .2 Decrease in reactivity during operation at power
- .3 Increase in reactor heat removal
- .4 Decrease in reactor heat removal

- .5 Loss of ultimate heat sink
- .6 Loss of primary coolant
- .7 Anticipated transient with failure of reactor shutdown
- .8 Failure of the nuclear power conversion system
- .9 Failure of the electrical systems
- .10 Failure of support systems

Note: This requirement should be specially considered for non-water cooled and small modular reactors.

4.7.2 The Safety Assessment should also take account of possible combinations of internal and external events and hazards that could challenge nuclear safety.

## Section 5

### Design, Construction and Equipment

#### 5.1 FNPP Arrangements

5.1.1 The FNPP should be segregated into areas classified in accordance with Section 6 on the basis of radiation hazards actually or potentially present.

5.1.2 The Nuclear Reactor Compartment should be located or protected to minimize damage in case of collisions, grounding and hazards arising from other equipment onboard the FNPP, missiles and other sources specifically identified by the safety assessment.

5.1.3 The Nuclear Reactor compartment should be segregated fore and aft by cofferdams or suitable bulkheads, extending from the double bottom to the bulkhead deck (as relevant and applicable), providing adequate protection against external damages, fires or explosions.

5.1.4 The use of cofferdams and double bottoms comprising the boundaries of the Nuclear Reactor compartment should be restricted to the carriage (if any) of non-potable water.

5.1.5 The Nuclear Reactor compartment should be so designed as to facilitate the salvage of the Nuclear Reactor or recovery of its essential parts from the FNPP in the event of wreck, without endangering the safety of the Nuclear Reactor installation in normal service.

5.1.6 A safety enclosure should be provided to:

- .1 Surround the containment structure and any significant source of radioactivity associated with the nuclear power plant.
- .2 Control and confine the leakage of radioactive material to the other parts of the FNPP and to the environment from the intact containment structure in all Plant States
- .3 To prevent and to control (including monitoring, delaying, and processing) the releases of radioactive material to the other parts of the FNPP and to the environment from all other sources of radioactivity it may contain;
- .4 Ensure, when the primary pressure boundary and the containment structure are simultaneously opened for postulated operational purposes, that there remains at least one physical barrier between irradiated fuel and the environment with the leak and gas tightness and water tightness required for nuclear safety

Note: This requirement should be specially considered for non-water cooled and small modular reactors.

5.1.7 The safety enclosure should confine for treatment and for eventually controlled release to the environment:

- .1 radioactive material which may leak from the primary pressure boundary, or from a small line rupture outside the containment structure
- .2 radioactive material leaking from an open containment structure, or from high or medium level waste storage containers within the safety enclosure
- .3 systems containing and treating radioactive material during nuclear reactor operational or refuelling states

**Note:** This requirement should be specially considered for non-water cooled and small modular reactors.

5.1.8 All bulkheads and other boundaries forming the safety enclosure should be gastight, of all-welded construction and comply with Fire Safety Requirements as provided in Part 6 of Main Rules. Piping and electrical penetrations in the safety enclosure should ensure that the bulkhead or boundary remains gastight and has fire protection equivalent to that of the safety enclosure.

5.1.9 The safety enclosure should be located entirely within the nuclear reactor compartment and within the structural boundaries designed to protect it and its contained equipment from the external hazards of marine application. The enclosure may include penetrations and personnel access openings, which must be capable of maintaining the requisite leak and gas tightness.

5.1.10 The fore and aft boundaries of the safety enclosure should be within the cofferdams or other structure forming the nuclear reactor compartment and may be integrated with such structures.

5.1.11 The longitudinal watertight, gastight bulkheads forming the boundaries of the safety enclosure should be located at a distance inboard of the FNPP's side not less than the limits of penetration determined in subdivision and damage stability requirements.

5.1.12 A containment structure should be provided to carry out the following safety functions:

- .1 Confinement of radioactive material in normal operation and in accident conditions by providing a gas and leak tight barrier against a release of radioactive material from the reactor
- .2 Protection of the reactor against natural and human induced external events.
- .3 Radiation shielding in normal operation and in accident conditions

5.1.13 The following requirements should be complied by the containment structure:

- .1 the containment structure should be within the safety enclosure
- .2 the primary pressure boundary should be located within the containment structure
- .3 The containment structure should be designed to withstand the applicable loads in normal conditions as well as those loads during accident conditions including those which arise as consequences of the release of radioactive material from the reactor
- .4 the containment structure should be designed to afford adequate protection against damage arising from any Plant States
- .5 penetrations of the containment structure should withstand the internal conditions occurring under any Plant States
- .6 isolation valves should be provided on all lines penetrating the containment structure and should be located as close to the boundary as practicable; it should be possible for such valves to be remotely controlled and automatically operated as the piping or trunked service requires and as necessary for automatic isolation of the containment structure.
- .7 during the nuclear power plant operation, the need for access to the containment structure for personnel should be kept to a minimum (this is not a classification requirement but is offered as a practical recommendation)
- .8 cleaning and cooling of the air within the containment structure to maintain the humidity, temperature and activity design values for all Plant States
- .9 Where a closed air circulation system is fitted, provisions should be made to ensure the air quality meets acceptable health standards before entry of personnel

- .10 where an open flow-through system is fitted, provision should be made for rapidly and automatically sealing all air ducts under conditions that may involve abnormal release of radioactive material into the containment structure. It should be demonstrated that the sealing arrangements will operate reliably in a time commensurate with the development of the fault and in the conditions prevailing at the time of the accident
  - .11 where provision is made to vent a containment structure to atmosphere after any postulated Plant States, such venting should be capable of being controlled and monitored for radioactive material and hydrogen and should pass through high-efficiency filters to ensure that the dose limits are not exceeded
  - .12 the containment structure venting system should not be used as a short-term pressure suppression system, nor should high-efficiency emergency filters be used except under those Plant States that release radioactive material into the containment structure
  - .13 the design efficiency of high-efficiency filters should be declared in the FNPP's Safety Assessment, and equipment to verify the efficiency values declared should be provided on board.
  - .14 provision should be made to control and monitor activity levels inside the containment structure under appropriate Plant States;
  - .15 deformation to hull structures and the safety enclosure from design basis events should not affect the structural integrity and gas and leak tightness of the containment structure, nor cause its buckling or plastic instability
  - .16 the containment structure should withstand the loads that could be imposed during accident conditions including sinking (or deliberate scuttling) of the FNPP or any other energetic events that could occur
  - .17 if devices such as pressure balancing valves are used to prevent collapse of the containment structure due to external overpressure following sinking, due attention should be paid to the gas and leak tightness of the containment structure after completion of pressure compensation.
  - .18 Safety related components within the containment structure should be qualified to withstand the most severe environmental conditions to which they may be subjected in accident conditions with sufficient margin
  - .19 the design should take account of the service temperatures and other conditions of the containment structure material during operation, maintenance, testing, and postulated accident conditions.
- 5.1.14 Penetrations on the boundaries of the nuclear reactor compartment, the safety enclosure and the containment structure, should be kept to a minimum.
- 5.1.15 Areas and equipment essential to FNPP and nuclear power plant safety should be arranged, taking into account the following:
- .1 disposition of such areas and equipment should ensure in the best way possible their protection against damage in the event of an internal or external accident. Safety Class 1 and other systems containing radioactive material including high-level radioactive waste which require protection of their integrity in case of a collision, should be located inboard of the collision protection.
  - .2 layout features should include adequate physical separation of redundant and diverse systems and components important to the safe operation of the FNPP and the nuclear reactor.

- .3 machinery having a potential for missile generation should be oriented or shielded so as to minimize missile effects to FNPP and nuclear reactor equipment.
- .4 the nuclear reactor control room should be in the least vulnerable position (to fires, missiles resulting from explosions, toxic substances, radioactivity, etc.) but as near as possible to the nuclear reactor and associated machinery/ equipment as possible to keep service lines short.
- .5 those systems (including their power supply) which are provided to ensure fundamental safety functions in the event of a failure in the principal system, should be functionally independent of and physically segregated from and diverse from the principal system. Wherever practicable, segregation by fire resistant and watertight structures should be adopted.
- .6 an emergency control position should be provided which is separate and remote from the nuclear reactor control room. From this position, it should be possible for an operator to bring the nuclear reactor to a safe stable shutdown condition while maintaining residual heat removal. An incident or accident which causes damage to the nuclear reactor control room should not impair the function of the emergency control position and vice-versa.
- .7 the emergency control position should be functionally connected with the onboard safety center so that, in case of emergency, a reactor fast shutdown (SCRAM) procedure could be performed.
- .8 Redundancy of electric power supply to the nuclear reactor control room and the emergency control position should be provided.
- .9 shielding against nuclear radiation should be arranged so that manning of essential control positions is possible for a reasonable period following Plant States 1 to 4. Measures should be taken to prevent inadvertent damage to such shielding.

5.1.16 Weather deck drains and drains from compartments not containing radioactive materials or systems should not pass through the safety enclosure.

5.1.17 An adequate number of portable radiation measurement devices should be available onboard.

5.1.18 The design of containment structure and the safety enclosure should take into account and include measures for:

- .1 Initial and periodic pressure testing
- .2 Periodic inspection and maintenance
- .3 Testing for gas and leak tightness
- .4 System isolation

## **5.2 Ventilation**

5.2.1 Ventilation systems serving spaces which contain or may contain radioactive material should be independent of and segregated from other ventilation systems. They should also be segregated from all spaces outside the controlled area, except where the ducts and stacks are suitably provided with shielding, protected against external accidents, and enclosed sufficiently gastight. Ventilation systems should comply with the relevant requirements of IRS Main Rules.

5.2.2 Ventilation intake locations for all spaces should be arranged to avoid the re-entry of released radioactive gases (as may be applicable).

5.2.3 Exhaust ventilation systems serving spaces which contain or may contain radioactive material should be monitored and controlled for possible radioactivity in accordance with Section 8. The location of exhaust outlets should be selected so as to avoid accidental contamination of any area of the FNPP.

5.2.4 Provision should be made for prevention of accumulation of smoke and toxic materials from internal and external sources which could lead to loss of visibility, asphyxiation or prevent crew members from effectively discharging their duties within the nuclear reactor control room or emergency control position.

5.2.5 Redundancy for essential ventilation and exhaust system active components should be provided. At least two standby fans should be fitted and arranged to start automatically in the event of failure of any of the running fans. In the event of activation of the standby fans, a visual and audible alarm should be activated in the main nuclear reactor control room.

5.2.6 For ventilating air flows from one space to another space, the flow should be from areas of lower potential airborne contamination to areas of higher potential airborne contamination.

5.2.7 Ventilation and filtration arrangements should maintain an underpressure within the safety enclosure even when one entrance is open.

### **5.3 Collision Protection**

5.3.1 Collisions considered in this section include collisions with fixed and floating objects.

Note: If the FNPP is located in a sheltered location protected with a breakwater and it is ensured through appropriate means and procedures that no other floating objects or vessels can be present within its vicinity, then collisions with floating objects during normal operation may not be necessarily considered subject to satisfactory evaluation of such means and procedures by IRS. Notwithstanding this, the mooring and berthing loads during such mooring of the FNPP at a sheltered location protected with a breakwater should be considered and demonstrated through calculations that such berthing loads do not cause damage to the watertight integrity of the FNPP. Such loads should also consider failure of the mooring lines and subsequent impact of the FNPP with the breakwater structure.

5.3.2 Collision protective structures should be provided against a collision which is a design basis accident to the satisfaction of the IRS, such that protection is provided to prevent penetration of the watertight, gastight boundaries of the safety enclosure by the striking or struck object. The protective structures in way of nuclear reactor compartment should be determined. The transition from the collision protection structure to the surrounding structures should ensure structure continuity.

5.3.3 The analysis of the collision protection should be part of the Safety Assessment. The analysis should take into account the likelihood of possibility of events such as the collision of a ship (who has lost propulsion and steering capabilities) with the FNPP. It should also consider the following:

- .1 proof by calculation, model demonstration, etc., of the efficiency of the collision protective structure to prevent exceeding the penetration limit considered in the FNPP design.
- .2 location of nuclear reactor compartment
- .3 subdivision and stability of the FNPP, including damage stability
- .4 residual hull strength in damaged conditions
- .5 displacement, speed and bow shape of striking ship
- .6 risk of fire and explosion
- .7 effects on equipment, systems and components

5.3.4 The assessment of the effects of collision the adequacy of the collision protection should be in accordance with methods or techniques agreed with IRS.

## 5.4 Protection of the Nuclear Reactor Compartment against damage from stranding and grounding

5.4.1 A double bottom should be fitted under the nuclear reactor compartment, sufficient for the protection of the nuclear reactor and safety related systems, including high level radioactive material storage areas. The depth of the double bottom under the nuclear reactor compartment should provide protection against bottom damage of the extent given in 3.3.2, but in no case should the bottom of the safety enclosure be less than the greater of B/15 or 2 metres above the bottom of the FNPP or be below the inner bottom plating.

Note: IRS will specially consider alternative proposals for the minimum size of the bottom of the safety enclosure

5.4.2 A double bottom of sufficient depth to withstand the assumed damage (see 5.4.1), should be provided under the nuclear power conversion system spaces.

5.4.3 The longitudinal strength of the FNPP hull should be evaluated taking into account damage to the primary structure in stranded conditions.

## 5.5 Fire Safety

5.5.1 All systems should be designed, arranged, and located in accordance with Part 6 of the Main Rules to minimize the probability and effect of fires and explosions. Where safety systems are to comply with their safety functions in case of a fire, segregation by suitable fire protection should be provided between redundant sections of the system or its subsystems.

5.5.2 Additional fire protection (structure, equipment and systems) may be required to ensure that the integrity of the shielding, the containment structure, the safety enclosure, and essential nuclear reactor safety systems is maintained, such that an onboard fire does not prevent safe shutdown of the nuclear reactor nor the maintenance of it in that state.

5.5.3 All spaces containing safety systems and equipment essential to the safety of the NPCCS and personnel should be fitted with a fire detection and alarm system, and a remote fire suppression system which uses an agent that is non-corrosive. Consideration should be given to the following:

- .1 use of fire-extinguishing agents that permit easy decontamination.
- .2 limited use of ionization detectors in spaces which may have high radiation levels.
- .3 limiting or controlling releases of potentially harmful and flammable substances as a consequence of overheating, fire, firefighting agents etc.
- .4 Suitable design, the use of structural fire protection, and the use and placement of fire protection equipment should minimize the probability of hazard or damage to the nuclear reactor, the NPCCS, and its control systems resulting from a fire in a non-nuclear section of the FNPP .
- .5 At least two means of escape should be provided from the main nuclear reactor control room and from the compartment in which the emergency nuclear reactor control position is located. Each escape route should provide effective fire shelter from the compartment to the weather deck.
- .6 Within spaces such as the nuclear reactor compartment and spaces containing equipment essential to the continued safe operation of the nuclear reactor and the NPCCS, the use of combustible substances and systems requiring combustible substances should be avoided; provided that, where use of such substances cannot be avoided, appropriate equipment and management procedures should be described in the Operating Manual.

- .7 Systems within spaces such as the nuclear compartment and spaces containing equipment essential to the continued safe operation of the nuclear reactor and the NPCCS or necessary to FNPP's operation, such as standby generating sets or auxiliary power sources, should be segregated and physically separated by structural fire protection and be provided with individual fire-extinguishing equipment.
- .8 Risk of explosion or fire originating from systems or equipment present on the FNPP, or external sources should be analysed. Where required by risk analysis, additional suitable fire protection arrangements should be provided.

## **5.6 Access Openings**

5.6.1 Access openings in boundaries of the nuclear reactor compartment or in the boundaries of spaces within the nuclear reactor compartment which form watertight, gastight or fire protection divisions, should be fitted with closures which will maintain the integrity of the division in which they are located. Where necessary for security or safety purposes, doors or appliances for closure of such access openings should be provided with appropriate arrangements for local and remote operation. Provision should also be made, by airlock arrangements, if necessary, to ensure that required air pressure differentials, where provided between adjacent compartments are not rendered ineffective during operation of access doors.

## **5.7 Security and Protection of the Nuclear Fuel**

5.7.1 Security and protection of the nuclear fuel should be undertaken in accordance with statutory requirements, as relevant and applicable.

5.7.2 Security measures against sabotage should be embedded in the design and the operation in order to achieve protection of the FNPP and fissile material on board. Security and safety measures should be consistent and harmonized.

5.7.3 No security measure should prevent or hinder the immediate and safe egress of persons from any compartment in the FNPP in the event of a fire or other emergency, nor prevent entry into a compartment as may be required for the performance of safety functions.

## Section 6

### Nuclear Power Plant Systems

#### 6.1 Design of Nuclear Power Plant Systems

6.1.1 This section elaborates requirements for the nuclear power plant systems.

Note: The requirements within this Section are subject to evaluation based upon the boundary conditions document (see Section 1.3).

6.1.2 The design of nuclear power plant systems should permit periodic in-service inspection and testing without loss of safety function.

6.1.3 Safety related structures, systems and components should comply with their safety class requirements.

6.1.4 All systems essential to operation or safety of the reactor should be capable of being manually controlled. This should be in addition to the automated actions which are provided.

6.1.5 The nuclear reactor should not rely on operator actions in the short-term following any initiating event. Automatic actuation of safety systems should be provided where rapid safety system action is required. The design of the control system should ensure that an operator can resume control of the safety protection systems but cannot negate correct safety system action.

6.1.6 Safety systems should be capable of carrying out their safety functions even if a single failure occurs that leads to the loss of capability of any component in the system including active and passive failures.

6.1.7 Attention should be paid to interfaces between the reactor and non-nuclear areas of the FNPP, to ensure maintenance of nuclear and FNPP safety.

#### 6.2 Nuclear Power Plant - General

6.2.1 In general, the design, construction, testing and commissioning of the following systems and components relevant to the Nuclear Power Plant onboard should be in accordance with the statutory requirements :

- .1 Nuclear Reactor(s) and Fuel
- .2 Primary Coolant Loop
- .3 Secondary Coolant Loop
- .4 Instrumentation and Automation Systems
- .5 Reactivity Control Systems
- .6 Residual Heat Removal Systems
- .7 Emergency Reactor Core Cooling Systems
- .8 Reactor Protection Systems
- .9 Fuel and Spent Fuel Storage Systems (including their safety systems)

6.2.2 The design of the systems and components in 6.2.1 should account for the effects that arise during normal operation and in accident conditions including loads that arise from:

- .1 FNPP inclinations (please see 4.3.10)
- .2 FNPP motions and accelerations
- .3 Internal Pressure
- .4 Induced vibrations due to waves including wave impact, machinery, and other vibration sources.
- .5 Reactor and FNPP design basis accidents.
- .6 Inertial loads and flow variations caused by flow redistribution due to FNPP motions
- .7 Thermal loads

The parameters enumerated as above should be submitted for review by IRS and the statutory authorities.

6.2.3 Ultimate, Fatigue and Accident Limit States should be considered for the evaluation of the loads as listed in 6.2.2. The loads mentioned in 6.2.2 should not preclude the reactor from being safely shut down and the safe removal of residual heat.

6.2.4 The structural integrity of the reactor core should be maintained during normal operation and in accident conditions.

6.2.5 The structural integrity of the core should withstand the anticipated radiation levels, mechanical loads and chemical loads that could occur during normal operation and in accident conditions.

6.2.6 The core geometry should provide for adequate reactivity control during normal operation and in accident conditions.

6.2.7 The core geometry should allow adequate core cooling during normal operation and in accident conditions with an adequate flow of primary coolant through the core.

6.2.8 The performance of reactivity control and reactor heat removal should take account of the motion of the during normal operation and in accident conditions.

6.2.9 The Safety Assessment should demonstrate that there are adequate safety margins in the design of the reactor core and it's support structures taking account of uncertainties.

6.2.10 It should be demonstrated by analyses and/or tests that there is no flow-induced vibration in the core and no vibration-induced effects that would endanger safe reactor operation.

**Note:** The requirements in 6.2.1 – 6.2.10 are not classification requirements and primarily come under the purview of the national nuclear regulatory body for consideration. However, these are provided here as recommendations to be considered keeping in view the response of reactor core to events within a maritime environment.

### **6.3 Reactivity Control**

6.3.1 At least two independent, reliable and effective reactivity control systems should be provided which are diverse in design and capable of maintaining subcriticality of the reactor core following shutdown from normal operation or in accident conditions.

6.3.2 The reactor shutdown systems should be able to operate automatically in accident conditions which includes events when the nuclear reactor compartment is flooded, the FNPP is submerged or it is inclined at an angle as defined in the Safety Assessment.

6.3.3 The reactor shutdown systems should be designed for and be capable of shutting down the reactor automatically and maintaining subcriticality at all angles of inclination of the FNPP that could occur in accident conditions.

6.3.4 In addition, the reactor fast shutdown (SCRAM) system should operate automatically at smaller inclinations for safety reasons as elaborated below:

- .1 The reactor shutdown systems should be capable of reducing the reactor power rapidly so that the reactor core and primary circuit are maintained within their design limits.
- .2 Both reactor shutdown systems should be capable of operation to shut down and hold down the reactor following single failures in either system.

6.3.5 The frequency of initiating events leading to an unanticipated reactivity increases should be minimized and not lead to situations which pose a radiological hazard to the public, crew or environment above the specified limits.

6.3.6 The effect of postulated reactivity accidents should not result in damage to the primary coolant circuit or prevent shutting down the reactor.

6.3.6 The reactor core should have a negative temperature coefficient of reactivity at all times.

6.3.7 The reactivity control systems should be fully operable within all design conditions of the FNPP and be capable of:

- .1 Functional testing
- .2 Periodic calibration of instruments throughout the entire range of reactor power
- .3 Verification of proper functioning of instrumentation

6.3.8 It should be possible to initiate and monitor the operation of the reactor shutdown systems from the main reactor control room or from the emergency reactor control room if the main reactor control room is rendered non-operational.

6.3.9 Failure of any control component should not prevent the safe shutdown of the reactor.

6.3.10 Means should be provided for testing reactor control systems while in operation to detect and, where possible, repair failed components, without reducing the system's capability of controlling the reactor in a safe and stable manner.

6.3.11 Appropriate measures should be provided to protect the persons in the main nuclear reactor control room after anticipated operational occurrences and accident conditions including fire protection, radiological protection systems and ventilation systems.

6.3.12 Instrumentation should be provided for:

- .1 monitoring the main parameters involved in the fission process, the integrity of the reactor core, the reactor coolant systems and the containment for the nuclear reactor.
- .2 Obtaining essential information on the nuclear power plant that is necessary for its safe and reliable operation.
- .3 Determining the status of the nuclear power plant in accident conditions.

.4 Supporting decision making during management of accident.

6.3.13 The control system should be designed to control reactor power, in response to operational demand, under all anticipated sea states during normal operation, abnormal operational occurrences and in accident conditions.

6.3.14 To the extent practicable, the complete control system should be so designed that no operational restrictions are imposed upon the FNPP that would not also apply to a conventional terrestrial nuclear power plant.

6.3.15 The control systems provided for the nuclear reactor should be appropriate and reliable to maintain and limit the relevant nuclear reactor operating parameters within the specified safe operational ranges.

6.3.16 Reactor control should be derived from diverse measurement parameters. A sufficient level of redundancy should be provided for the measurement of reactor control parameters.

6.3.17 Design of the reactor control systems should consider the eventuality of faulty indications and incorporate appropriate means to address such eventuality.

6.3.18 Interlocks should be provided within the control systems to prevent inadvertent operation by an operator which can lead to an unsafe situation.

**Note:** Para 6.3.16, 6.3.17, 6.3.18 do not constitute classification requirements. These are however enumerated here for further consideration during review of the boundary conditions document.

## **6.4 Primary Pressure Boundary**

6.4.1 The primary pressure boundary should be designed, fabricated, installed and tested to the engineering standards as specified by the national nuclear regulatory body.

6.4.2 Means should be provided for detecting loss of integrity of the primary pressure boundary.

6.4.3 Design provisions should be made for the static and dynamic forces imposed upon the system throughout its lifetime, from sources such as:

- .1 Loading induced by pressure and temperature variations including cyclic loads
- .2 Inertial loads imposed by FNPP motions and FNPP and reactor accidents
- .3 Vibration loads induced by sources internal or external to the system

6.4.4 The primary pressure boundary system should be adequately designed such that, when subjected to stress under operation, maintenance, testing and postulated accident conditions, the boundary behaves in a ductile manner.

6.4.5 The design should reflect consideration of service temperatures and other conditions affecting the containment material under these conditions, as well as the uncertainties in determining the following:

- .1 Material Properties
- .2 Effects of irradiation on material properties
- .3 Residual, steady-state and transient stresses
- .4 Sensitivity of non-destructive test equipment and test frequency

- .5 Materials and methods of construction should be selected with particular attention given to the following
- a. Suitability for use in nuclear and marine environments
  - b. Corrosion and erosion from the reactor coolant
  - c. Trace elements, present in construction materials in actual or potential contact with reactor coolant, that may be susceptible to activation and transport
  - d. Effects of neutron irradiation on material properties

6.4.6 Where applicable, overpressure protection of the primary pressure boundary should be provided which incorporates redundant safety relief valves that vent into a dedicated tank inside the containment structure.

6.4.7 The engineering design standards applied for the primary pressure boundary overpressure protection system should be equivalent to those for the primary coolant vessel as specified by the National Nuclear Regulatory Body. The design provisions should take into account static and dynamic forces as listed in 6.4.3.

**Note:** The requirements in this sub-section will be evaluated by IRS with regard to Classification as indicated in the boundary conditions document in so-far as the effects of the FNPP and marine environment (motions, accelerations, inclinations etc.) are concerned.

## **6.5 Secondary Coolant System**

6.5.1 The secondary coolant system should be designed, fabricated, installed and tested to the same engineering standards as those applied to the primary coolant system.

Note: It is anticipated that these standards would be specified by the national nuclear regulatory body and evaluation be performed as agreed in the boundary conditions document (see Section 1.3).

6.5.2 Design provisions should consider the static and dynamic forces imposed upon the system throughout its lifetime from the same sources as considered for the primary coolant system.

## **6.6 Residual Heat Removal**

6.6.1 Means should be provided for the removal of residual heat from the reactor core in the shutdown state such that the design limits for fuel, the nuclear reactor, primary pressure boundary and structures important to safety (containment structure, safety enclosure and their support structures) are not exceeded.

6.6.2 The residual heat removal systems should be designed to permit unmanned operation during and following all FNPP accident conditions, except for the following:

- .1 Capsizing while remaining afloat if this is not a design basis accident.
- .2 Sinking below a depth where it can be proven that flooding of the containment structure will remove residual heat for as long as is necessary.

6.6.3 The residual heat removal system should be capable of continuous operation for a period of time shown necessary by accident analysis.

6.6.4 The residual heat removal system should be designed with sufficient capacity, reliability and redundancy to ensure that reactor core integrity and capability to be kept cool are maintained under normal operation and accident conditions.

6.6.5 Passive residual heat removal systems should be incorporated into the design to the extent practicable.

**Note:** The requirements in this sub-section will be evaluated by IRS with regard to Classification as indicated in the boundary conditions document in so-far as the effects of the FNPP and marine environment (motions, accelerations, inclinations etc.) are concerned.

## **6.7 Instrumentation**

6.7.1 Appropriate and reliable control systems should be provided to maintain and limit the relevant process variables within the specified operational ranges.

6.7.2 The instrumentation in the reactor protection system should include functional diversity, equipment diversity and redundancy to provide a high level of reliability of the system.

6.7.3 The design of instrumentation should ensure continuity of its function under any anticipated service environment.

6.7.4 The reactor protection system should be designed so that it will continue to remain operable during normal operation and following design basis accidents including fire, explosion or damage in any region of the FNPP.

6.7.5 Design techniques such as testability, including a self-checking capability where necessary, fail-safe characteristics, functional diversity and diversity in component design and in concepts of operation should be used to the extent practicable to prevent the loss of a safety function.

6.7.6 The design of instrumentation should provide for rapid, unambiguous assessment of plant condition. Visual and audible alarms should be provided to contribute to the continuity of operation or safety.

6.7.7 All information essential to plant performance or to interpretation of malfunctions should be automatically recorded and be possible to be accessed or displayed when required.

6.7.8 Wherever useful for continuity of operation, safety or maintenance, indicators should be provided in the main nuclear reactor control room, locally and in the emergency nuclear reactor control room.

**Note:** The requirements in this sub-section will be evaluated by IRS with regard to Classification as indicated in the boundary conditions document in so-far as the effects of the FNPP and marine environment (motions, accelerations, inclinations etc.) are concerned.

## **6.8 Reactor Protection System**

6.8.1 A reactor protection system should be provided that has the capability to detect unsafe plant conditions and to initiate safety actions automatically to actuate the safety systems necessary for achieving and maintaining safe plant conditions.

6.8.2 Interference between protection systems and control systems should be prevented by means of separation, by avoiding interconnections or by suitable functional independence.

6.8.3 The reactor protection system should:

- .1 Continuously monitor appropriate reactor conditions
- .2 Automatically initiate action by the appropriate systems, such as the reactivity control system, to ensure that reactor system design limits important to safety are not exceeded.
- .3 Sense accident conditions and initiate action by systems and components important to safety.

6.8.4 The reactor protection system should include functional diversity, equipment diversity and redundancy to provide a high reliability of the system and can meet the single failure requirement.

6.8.5 The reactor protection system should be capable of being tested during operation without reducing the reliability of the system in responding in accident conditions.

6.8.6 The reactor protection system instrumentation required to operate Design Basis Accidents, Beyond Design Basis Accidents and Design Extension conditions should be demonstrated to be appropriate for operation during such conditions.

6.8.7 Failure of an instrument channel or malfunction of the instrument channel of the reactor protection system should cause an audible and visual alarm in the main reactor control room.

6.8.8 If a system important to safety is dependent upon computer-based programmes and equipment, appropriate standards and practices for the development and testing of computer hardware and software should be established and implemented throughout the service life of the system, and in particular throughout the software development cycle. *IRS Guidelines on Certification of Software for Computer Based Control Systems* and *Classification Notes: Type Approval of Cyber Secured Control System Components* may be referred in this regard.

## **6.9 Reactor Core Emergency Cooling Systems**

6.9.1 An Emergency Reactor Core Cooling System (ERCCS) should be provided to restore and maintain cooling of the core under accident conditions at the nuclear power plant where the integrity of the primary coolant boundary system is not maintained.

6.9.2 The ERCCS should have a suitable level of redundancy, diversity and segregation to provide sufficient reliability following the Postulated Initiating Events where it is required to operate.

6.9.3 The ERCCS should maintain the integrity of the fuel following a Postulated Initiating Event where the integrity of the primary coolant boundary system is not maintained.

6.9.4 An ample and diverse supply of core coolant should be provided at pressures and flow rates which are safe (to ensure that the reactor core remains undamaged), until long-term heat generated in the core can be safely removed by the residual heat removal systems.

6.9.5 The ERCCS should be operable from the main and emergency nuclear reactor control rooms.

6.9.6 The active components of the ERCCS should be capable of being tested at any time to ensure that they will perform satisfactorily when required.

## **6.10 Containment Heat Removal and Atmospheric Clean-up**

6.10.1 Provision should be made to control the pressure and temperature in the containment and to control any buildup of fission products or other gaseous, liquid or solid substances that might be released inside the containment and which could affect the operation of systems important to safety.

6.10.2 The containment heat removal system should have sufficient capacity to remove heat released to the containment structure under normal and accident conditions.

6.10.3 Means should be provided to reduce the concentration of fission products in the containment atmosphere and to prevent the buildup of gases that could sustain combustion or explosion.

6.10.4 Systems should be designed to permit appropriate inspection, maintenance and testing.

6.10.5 Each system should have sufficient redundancy and capability to perform its safety function, assuming a single failure.

## **6.11 Interface of FNPP Hull and Nuclear Power Plant**

6.11.1 Piping systems that extend outside the containment structure and which contain or may contain radioactive material should be fitted with double isolation valves and leak detection capability.

6.11.2 No interconnections should be provided between the FNPP's piping (non-nuclear) and that piping which contains or may contain radioactive material.

## Section 7

### Machinery and Electrical Installations

#### 7.1 General

7.1.1 This Section covers the main and auxiliary machinery and electrical systems required for FNPP operation. The main and auxiliary machinery should be constructed and installed in accordance with Part 4 of the Main Rules, as relevant and applicable. For machinery and electrical installations, directly connected with the safety of the nuclear power plant, relevant statutory requirements are to be complied with, also taking into account the requirements of this Section.

7.1.2 Adequate provision should be made to facilitate cleaning, inspection and maintenance of the nuclear reactor and auxiliary machinery, including arrangements for radioactive decontamination, where required.

7.1.3 Where there is a danger of failures leading to complete breakdown, damage or explosion, the nuclear power plant and the relevant auxiliary machinery should be provided with automatic shutoff arrangements.

Note: Consideration may be given to permit provisions for over-riding automatic shutoff devices. However, prior permitting manual over-ride on shut-off arrangements and service safety related equipment, its effect should first be assessed on a case-by-case basis to ensure that dangerous conditions cannot arise or are prevented by alternative means. If such provisions are requested, then these should be listed in the boundary conditions document (See section 1.3).

7.1.4 The inclination angles at which main and auxiliary machinery is to be capable of operation should be in accordance with Part 4 of the Main Rules.

#### 7.2 Bilge and Ballast Pumping Arrangements

7.2.1 Bilge pumping arrangements for all watertight compartments, except permanent ballast and cargo tanks, should comply with the requirements of IRS Main Rules.

7.2.2 Bilge, ballast and drainage systems should be arranged to prevent the spread of radioactive liquids.

7.2.3 Bilge pumping installations, serving compartments into which radioactive liquids may leak in normal service, should be separate from and independent of the FNPP's main bilge system, and should be adequate for all Plant States. Pumping machinery or piping containing radioactive material on a temporary or permanent basis should be adequately shielded.

7.2.4 The requirements of this subsection should be evaluated by IRS.

#### 7.3 Cooling Systems

7.3.1 Coolants of components connected to the primary coolant boundary, should be compatible with the materials normally in contact with the primary coolant.

7.3.2 The cooling systems essential services, machinery and auxiliaries should ensure supply and discharge of the ultimate cooling medium at all times. This includes periods when the FNPP is alongside a quay, from both port and starboard, and considering the different draughts of the FNPP.

7.3.3 Facilities should be provided to ensure uninterrupted and reliable cooling for essential auxiliaries when the FNPP is in dry dock. Shore supplies of cooling medium may be used; two independent connections should be provided.

## **7.4 Hydraulic and Pneumatic Systems**

7.4.1 For each compressed air or other gas system intended for nuclear safety functions, there should be provided at least two independent and segregated air reservoirs, each of sufficient capacity to fulfil the essential services for which the system is intended. Single failure of any active component of the compressed air or other gas system should be considered.

7.4.2 Where applicable, compressed air for control equipment should be dried, filtered and temperature conditioned.

7.4.3 The requirements of 7.4.1 and 7.4.2 also apply to the provision of pumps and accumulators where relevant and, in principle, to hydraulic systems if the function of the system affects nuclear reactor safety.

## **7.5 Electrical Installations - General**

7.5.1 The reliability of the electrical installations should be in accordance with the requirements for both nuclear reactor and FNPP non-nuclear electrical systems in Part 4 of the Main Rules.

7.5.2 In any Plant States up to and including Plant State 4, the electrical system as a whole, excluding the generating set dependent on the NPP, should be capable of shutting down the nuclear reactor and holding it in a safe state for at least 30 days assuming a single failure in the electrical system in addition to the initiating event which caused the Plant State.

7.5.3 The electrical installation should consist of a main electrical system and an emergency electrical system which comply with the requirements in Part 4 of the Main Rules.

7.5.4 The main electrical system is composed of main generators, standby generators and main distribution system which supply electrical power to both FNPP and nuclear reactor consumers.

7.5.5 Main Generators should maintain the FNPP in normal operational and habitable conditions, with the nuclear reactor in power generation mode, without recourse to either standby or emergency power generation.

7.5.6 Standby generators are those electrical generators which are independent of the NPP and are provided to replace inoperable main generators. They should supply those services necessary to provide normal operational conditions of safety and to maintain minimum comfortable conditions of habitability and to start up the NPP.

7.5.7 The emergency electrical system should be composed of emergency power sources and their associated distribution system which supplies electrical power to consumers essential to FNPP and nuclear reactor safety.

7.5.8 A transitional electrical power source is that power source which ensures an uninterruptable source of electrical power to specified consumers when other sources of electrical power are unavailable.

7.5.9 The design of the electrical power system should permit appropriate periodic inspection and testing of equipment important to nuclear reactor safety and FNPP safety.

7.5.10 The emergency electrical system and each section of the main electrical system, should be independently capable of providing sufficient power to the nuclear reactor safety systems, to ensure that:

- .1 the specified fuel design limits and other nuclear reactor design conditions are not exceeded as a result of any condition up to and including Plant States 4: and
- .2 The generating sets independent of the nuclear power plant should be such as to ensure that with any one of them out of operation, the remaining generators will be capable of providing the electrical services necessary for startup and to maintain minimum comfortable and habitable conditions during nuclear reactor startup. Emergency generators may be used for the purpose of startup if their capacity is sufficient to provide, at the same time, those services essential for FNPP safety.

**Note:** These requirements should be specially considered for non-water cooled and small modular reactors.

## 7.6 Main Electrical System

7.6.1 The main electrical system should be designed to address the following:

- .1 the failure of a single component of a generator of the main electrical system, together with its prime mover and auxiliaries:
  - a. should not involve a nuclear reactor trip
  - b. should allow the full electrical power necessary for maintaining the FNPP in normal operational and habitable conditions to be restored within a few minutes;
- .2 the failure of a single component of the main distribution system should not involve
  - a. a nuclear reactor trip;

**Note:** The time for restoration of full electrical power in 7.6.1.1 b above should be listed for evaluation within the boundary conditions document (see section 1.3).

7.6.2 The generating capacity should be sufficient to supply the full electrical power necessary for maintaining the FNPP in normal operational and habitable conditions.

7.6.3 The main electrical system should be capable of being supplied by at least one standby generating set.

7.6.4 The standby generators should have sufficient capacity to supply the electrical power necessary for startup of the Nuclear Power Plant, and for supplying those services necessary to provide normal operational conditions of safety and minimum comfortable conditions of habitability.

7.6.5 Standby generator sets should be designed to start up and accept load automatically as quickly as is safe and practicable upon the loss of voltage of its associated busbars. In order to ensure ready availability of systems necessary for FNPP safety, load shedding arrangements should be provided where necessary to disconnect automatically those circuits not essential for FNPP safety.

**Note:** The time for standby generators to startup and accept load automatically should be listed for evaluation within the boundary conditions document (see section 1.3).

7.6.6 The fuel supply system, for the standby generating sets should:

- .1 be of a design that will prevent a common mode failure from disabling all generating sets and be as close as practicable to the standby generator
- .2 be capable of being used by the emergency power generators
- .3 be sufficient for supplying any standby generator at full load for a time which is compatible with FNPP operations
- .4 not be rendered unavailable to any emergency generator by a condition disabling a standby generator

7.6.7 The main electrical system should be divided into at least two sections, each section having its own main switchboard, and each section being supplied by at least one main generator.

7.6.8 Main electrical system sections should be so arranged that Plant States 1 or 2 which disables one main electrical section should not disable another main electrical section.

7.6.9 Duplicated equipment fed by the main electrical system should be equally divided between main electrical sections and appropriately segregated. Distribution systems should be so designed and located as to minimize, to the extent practicable, the likelihood of their simultaneous failure under operating and postulated accident and environmental conditions.

## **7.7 Emergency Electrical System**

7.7.1 The emergency electrical system, and any generating sets independent of the Nuclear Power Plant which supply emergency loads, and the emergency distribution systems, should have sufficient independence, redundancy and testability to Perform their safety functions, assuming a single failure in any condition up to and including all Plant States. Means should be provided to safely connect the emergency electrical system with an external source of power supply. Such means should be available on both the port and starboard sides of the FNPP.

7.7.2 Any generating set provided to meet the requirements of 7.5.2 in order to supply emergency loads should comply with the requirements contained in these guidelines for emergency generating sets.

7.7.3 In addition to the emergency electrical system capacity required as per Part 4 of the Main Rules, sufficient electrical power capacity and supply should be provided to:

- .1 safely shut down the nuclear reactor
- .2 safely bring the nuclear reactor to a cold subcritical state and maintain it in that state
- .3 All nuclear reactor safety functions

7.7.4 The emergency distribution systems provided to meet the requirements of 7.5.2 should be segregated so that the initiating Plant States will not disable more than one emergency distribution system.

7.7.5 Each emergency switchboard should be capable of receiving electrical power from either section of the main electrical system and an external source of power supply.

7.7.6 Nuclear Reactor protection and safety systems and related safety loads should be fed by the emergency distribution system.

7.7.7 Each emergency generator should be capable of being started and controlled from the switchboard to which it is connected and should be located in the compartment with the emergency switchboard to which it is connected.

7.7.8 The emergency power supply should be capable of being independently started from the main nuclear reactor control room, emergency control position and at the location of the emergency generating set. An incident in any one of these spaces other than the location of the emergency generating set should not prevent the startup and control of the emergency generator from the emergency switchboard.

7.7.9 Electrical equipment and non-electrical machinery and systems unrelated to the emergency function should not be located in the spaces where the emergency generators, controls and switchboards are located.

7.7.10 Each emergency generator should automatically start on a signal of loss of voltage on its associated busbar.

7.7.11 The emergency electrical system should assume its electrical loads within a short period of time from startup. This time should be consistent with the requirement defined by Plant States 1 to 4.

**Note:** This period of time should be listed for evaluation within the boundary conditions document (see section 1.3).

7.7.12 The emergency electrical system should be capable of periodic full load and starting time testing, under simulated conditions of power failure. The emergency electrical source should be independent of other electrical supplies, to the extent that faults on those supplies will not affect the required reliability and effectiveness of the emergency system.

7.7.13 The design of the emergency electrical system should be such that direct synchronizing of power sources should not be required to meet an emergency demand.

7.7.14 Sufficient fuel should be available to emergency generator sets for a minimum of 30 days operation after any Plant States, up to and including Plant States 4. Alternatively, IRS will consider arrangements such that external power supply can be made available to fulfil the functions of the emergency generators

## **7.8 Transitional Power Source**

7.8.1 Transitional power sources should be provided such that they have sufficient independence, redundancy and testability to perform their safety functions, taking into account any single failure in normal operation and accident conditions.

7.8.2 Transitional power sources may be omitted if it is verified that the consumers defined in 7.8.4 have an uninterruptable power supply assuming a single failure in any condition up to and including Plant States 4, as defined in 7.5.2, and the requirements of 7.8.3 to 7.8.6 are met.

7.8.3 The transitional power sources should be kept segregated so that a Plant State 1 to 4 does not disable more than one redundant power source.

7.8.4 Each transitional power source should be designed to supply for a minimum period of 30 minutes the following nuclear reactor consumers

- .1 the controls and monitoring equipment of the nuclear reactor safety system
- .2 radiation protection monitoring systems
- .3 other nuclear reactor controls and monitoring equipment used for anticipated Plant State 1 to 4; the supply of other equipment should be in accordance with statutory requirements, as relevant and applicable.

7.8.5 DC electrical equipment should operate satisfactorily with the following simultaneous variations, from their nominal value, when measured at the consumer input terminals:

- .1 When supplied by DC generator(s) or a rectified AC supply
  - a. Voltage tolerance (continuous)  $\pm 10\%$
  - b. Voltage cyclic variation deviation 5%
  - c. Voltage ripple 10%  
(AC rms over steady state DC voltage)
- .2 When supplied by batteries
  - a. Equipment connected to the batteries during charging: Voltage tolerance +30%, -25%;
  - b. Equipment not connected to batteries during charging: Voltage tolerance +20%, -25%.

7.8.6 Different voltage variations as determined by the charging/discharging characteristics, including ripple voltage from the charging device, may be considered. When battery chargers/battery combinations are used as DC power supply systems, adequate measures should be taken to keep the voltage within the specified limits during charging, boost charging and discharging of the battery.

7.8.7 Accumulator batteries should comply with the requirements in Part 4 of the Main Rules.

7.8.8 Batteries used exclusively for the NPP may be located below the uppermost continuous deck, provided that this does not affect the integrity of the system as specified in 7.8.1.

## **7.9 Shore Power Connection**

7.9.1 Shore power connections should be provided, through which power may be supplied to any section of the main electrical system. Please refer to the IRS *Guidelines on Shore Connection Systems on Ships*.

## **7.10 Electrical Wiring and Component Insulation**

7.10.1 Cables which are not associated with safety of the nuclear power plant and components should be type approved and comply with the requirements in Part 4, Chapter 8 of the Main Rules.

7.10.2 Electrical wiring and components which are to fulfil their safety function after a postulated accident should withstand the environmental conditions (pressure, temperature moisture, etc.), associated with that accident.

7.10.3 Cables to redundant safety systems, switchgear and consumers should be routed on fully segregated and/or protected paths.

## **7.11 Penetrations by Electric Cables**

7.11.1 Electrical cable penetrations on the containment structure, safety enclosure and primary pressure boundaries, should be kept to a minimum consistent with safety considerations. Penetrations should not impair the required gas and leak tightness and fire resistance of boundaries nor prevent satisfactory inspection and testing.

7.11.2 Cables to redundant safety systems, switchgear and consumers should be routed on fully segregated and/or protected paths.

## Section 8

### Radiation Protection

#### 8.1 General

8.1.1 This Section indicates the requirements for radiation protection with regard to the construction and operation of FNPP.

**Note:** Evaluation of compliance with the requirements in this section should be specified in the boundary conditions document (see section 1.3).

8.1.2 In this Section, the expression "as low as reasonably achievable" is used. In the context of radiation protection, ICRP has indicated that this is intended to imply the optimization of radiation protection arrangements whereby activities involving exposure to radiation are carried out at a level of exposure (within dose-equivalent limits) such that further reduction would not justify the incremental cost required to accomplish it.

#### 8.2 Design for Radiation Protection

8.2.1 Radiation Protection should be provided for ensuring that radiation doses to persons onboard the FNPP will be maintained below the specified dose-equivalent limits and will be kept as low as reasonably achievable. Distance, occupancy time and shielding should be considered for controlling exposure.

8.2.2 Radiation sources on the FNPP should be identified, and exposures and radiation risks associated with them should be kept as low as reasonably achievable, the integrity of the fuel cladding should be maintained, and the generation and transport of corrosion products and activation products should be controlled.

8.2.3 Materials used in the manufacture of structures, systems and components should be selected to minimize activation of the material as far as reasonably practicable.

8.2.4 Provision should be made for preventing the release or the dispersion of radioactive substances, radioactive waste and contamination at the plant.

8.2.5 The design of the FNPP should ensure that, when the reactor is operating normally or is shut down, no persons on board will, as a result of its operation, be subjected to radiation or contamination levels in excess of the defined dose-equivalent limits.

8.2.6 Where appropriate, safety factors should be adopted at the design stage to provide margins for contingencies. Such safety factors should be clearly indicated in the Safety Assessment.

8.2.7 The design of the FNPP and the nuclear reactor should be such that there is no significant increase in the background radiation level at the operating site/ location or a berth, due to the operation of the FNPP in Plant State 1 and 2 conditions.

8.2.8 The FNPP should be divided into zones that are related to their expected occupancy, and to radiation levels and contamination levels in operational states (including refuelling, maintenance and inspection) and to potential radiation levels and contamination levels in accident conditions.

8.2.9 The FNPP layout should be such that the doses received by operating personnel during normal operation, refuelling, maintenance and inspection can be kept as low as reasonably achievable, and due account should be taken of the necessity for any special equipment to be provided to meet these requirements.

8.2.10 Shielding should be provided so that radiation exposure is prevented or reduced to acceptable levels.

8.2.11 Taking into account the nature of the radiological hazard in controlled and supervised areas, access barriers, protective clothing, personnel monitors, washing facilities and changing rooms should be located, as appropriate, between controlled or supervised areas and adjacent uncontrolled areas, to prevent the transfer of contamination from one area to another. Facilities should be provided for the decontamination of persons onboard and FNPP equipment.

8.2.12 Warning signs should be placed at the entrance to a controlled or supervised area to indicate the hazards.

8.2.13 Access to a controlled area should be limited to authorized persons and their entrance and exit should be registered.

8.2.14 Radiation protection arrangements should be such that, under normal operating conditions, no restrictions are necessary on the operations of the FNPP. Radiation protection arrangements should also be provided considering the case when the FNPP is in drydock.

8.2.15 Within the uncontrolled areas, the dose rates at power for Plant State 1 and 2 conditions should not exceed the applicable dose rate limits and should be reduced as far as is reasonably achievable.

8.2.16 The design should be such as to minimize the spread of radioactive materials or contamination as far as reasonably achievable.

8.2.17 All parts of the FNPP in which radioactive materials or contamination may be present should be identified and appropriate design measures taken to ensure that the spread of radioactive material or contamination into other parts will be minimized and that any necessary decontamination procedures can be carried out safely within the relevant dose-equivalent limit.

8.2.18 Appropriate design measures should be incorporated to allow for the decontamination of surfaces and equipment and to permit proper control of the radioactive wastes which arise.

8.2.19 Structural and surface irregularities in all systems and equipment containing radioactive materials should be avoided.

8.2.20 The design of the reactor and its associated plant (including the waste management installation), their shielding and containment provisions and their location on the FNPP should be such that any release of radioactivity arising from Plant State 4 conditions will not lead to the dose-equivalent limits being exceeded.

8.2.21 The dose equivalent from external irradiation, together with the committed dose equivalent arising from intakes of radioactivity, which could be received at the outside surface of the hull or its vertical projection where appropriate should be within the dose-equivalent limits for any Plant State 4 conditions.

8.2.22 Those parts of the FNPP which would be required to be occupied by nuclear plant operators and FNPP crew during any Plant State 4 event should be so located and/or shielded as to ensure that doses to the persons staying in such spaces for the whole course of the event would not exceed the applicable dose-equivalent limits.

8.2.23 Plant equipment subject to frequent maintenance or manual operation should be located in areas of low dose rate to reduce the exposure of workers.

8.2.24 Arrangements should be provided to ensure that servicing, maintenance and in-service inspection can be carried out safely, with neither unacceptable exposure of personnel to radiation nor unacceptable release of radioactive material to the environment.

### **8.3 Protection of Persons**

8.3.1 Radiation doses received by the crew, other persons on board and members of the public, as a result of operation of the FNPP in Plant State 1, 2 and 3 conditions should be kept as low as is reasonably achievable and within the appropriate dose-equivalent limits recommended by ICRP.

8.3.2 Surface or airborne contamination as a result of Plant State 1, 2 and 3 conditions should be within limits that are derived from the relevant dose-equivalent limits.

8.3.3 The design basis limit for doses to persons on board the FNPP and members of the public in the event of a Plant State 4 condition should not exceed twice the relevant annual dose-equivalent limit for occupationally exposed persons.

8.3.4 The FNPP should be provided with sufficient numbers and adequate means of individual protection, including filter respirators and air-supplied sets, to deal with Plant State 1 to 4 conditions.

8.3.5 Documented procedures should be established and available onboard that provide adequate radiation protection to persons under all Plant States including the following:

- .1 Systematic and thorough surveying of work areas prior to commencement of work.
- .2 Planning of work and worker occupancy time in the work area, to ensure that individual radiation exposures are kept as low as is reasonably achievable and within the specified limits.
- .3 Estimation of individual radiation exposures for the work planned.
- .4 Selection of the necessary personnel dosimeters, protective clothing, respiratory, and communication equipment for each worker.
- .5 Administrative controls, to preclude inadvertent exposure to unexpectedly high radiation levels during maintenance and inspection.
- .6 Prophylactic measures and decontamination of contaminated workers and unshielded surfaces.
- .7 Radiation emergency procedures on board the FNPP including those considering FNPP at drydock or a Port.

8.3.6 A recycling plan should be developed. Precautions and means to mitigate personnel risk during recycling should consider the following but not limited to the following:

- .1 Highly radioactive material and effluents from the reactor core
- .2 The coolants and components of the reactor primary circuit and other circuits of low level radioactivity.
- .3 Any other radioactive waste arising from decommissioning.

#### **8.4 Dosimetry and Radiation Monitoring**

8.4.1 Equipment should be provided to ensure that there is adequate radiation monitoring in all areas of the FNPP in normal operational states and accident conditions (design basis accidents and as far as practicable in design extension conditions).

8.4.2 Monitoring facilities, incorporating fixed or portable equipment, should be provided to indicate and record radiation levels, airborne and surface contamination levels, radioactive concentrations and flows which includes the following:

- .1 Measures to provide warning and, where necessary, take action if predetermined levels of radiation, contamination, radioactive concentrations or radioactive flows are exceeded.
- .2 Equipment to indicate and record radiation levels and activity concentrations in the coolant circuits and of all radioactive wastes stored on board and of all potentially radioactive discharges from the FNPP.
- .3 Equipment to indicate the activity concentration of the fluids in cooling circuits
- .4 Adequate supply of spare monitoring instruments and suitable on-board facilities for the maintenance and calibration of monitoring equipment

8.4.3 Stationary dose rate meters should be installed to monitor local radiation dose rates at plant locations that are routinely accessible by operating personnel and where the changes in radiation levels in operational states could be such that access is allowed only for certain specified periods of time. Stationary dose rate meters should be installed to indicate the general radiation levels at suitable FNPP areas in accident conditions.

8.4.4 Stationary monitors should be provided for measuring the activity of radioactive substances in the atmosphere in those areas routinely occupied by persons onboard the FNPP and where the levels of activity of airborne radioactive substances might be such as to necessitate protective measures. These systems should provide an indication. Monitors should also be provided in areas subject to possible contamination as a result of equipment failure or other unusual circumstances.

8.4.5 Indications of radiation levels and of airborne contamination levels in controlled areas should be presented at a central control location. This should include the main and emergency nuclear reactor control rooms.

8.4.6 The coolant circuits as well as the atmosphere inside the containment structure and the safety enclosure should be continuously monitored by separate systems that will give indication at a central control point and warning inside the safety enclosure if any significant increase in level is detected.

8.4.7 The data obtained from fixed monitoring equipment should be supplemented by data collected during regular patrols from portable monitors. Personnel used for such patrols should be trained in the use of the instruments employed. Stationary equipment and laboratory facilities should be provided for determining, in a timely manner, the concentrations of selected radionuclides in fluid process systems, and in gas and liquid samples taken from plant systems or from the environment, in operational states

and in accident conditions. Stationary equipment should be provided for monitoring radioactive effluents and effluents with possible contamination prior to or during discharges from the plant to the environment.

8.4.8 Instruments should be provided for measuring surface contamination. Stationary monitors (e.g. portal radiation monitors, and hand and foot monitors) should be provided at the main exit points from controlled areas and supervised areas to facilitate the monitoring of operating personnel and equipment.

8.4.9 Sufficient fixed radiation checkpoints should be established so that it is possible to compare radiation levels or contours within the FNPP periodically during the life of the FNPP with the original surveys made when the FNPP was commissioned.

8.4.10 An adequate number of fixed points should be selected, principally on plant within the safety enclosure.

8.4.11 Points outside the safety enclosure, both within the FNPP and on its exterior surface, should also be used.

8.4.12 Radiation levels or contours should be checked at full power, shutdown, berthing (if applicable) and drydocking.

8.4.13 Contours should be redrawn where necessary. In addition, means should be provided to monitor possible contamination in normally accessible areas of the FNPP.

8.4.14 Sufficient portable monitors for routine and emergency radiation surveys including beta, gamma and neutron survey meters, air samplers, and alpha/beta contamination monitors should be provided onboard.

8.4.15 The quantity of personal dosimeters carried on board should be adequate to meet the needs of normal service and should be sufficient for all persons onboard in the event of an accident.

8.4.16 The radioactive monitoring and recording systems should include the following:

- .1 Fixed and portable equipment for assessing the concentrations and amounts of gaseous and airborne particulate radioactive material which may be released to the environment.
- .2 Equipment to detect releases of radioactive material from the reactor core.
- .3 Installed equipment, including a suitable alarm system, to monitor from the gaseous discharge lines the rate of release of radioactivity and the total activity released.
- .4 Equipment to assess to a specified accuracy the activity concentration and total amount of liquid wastes in the collection, treatment and storage facilities.
- .5 Equipment to determine the levels of specified radioactivity isotopes in liquid wastes prior to their discharge to the marine environment.
- .6 Installed equipment, linked to a suitable alarm system and having the capability of automatically isolating the liquid waste discharge lines, to measure and record the activity concentration and the discharge flow rate where liquid waste discharge to the sea is permitted.

- .7 Equipment for assessing the levels and types of radiation emitted by solid radioactive wastes, prior to segregation and treatment.
- .8 Suitable procedures and testing and monitoring equipment to verify the correct operational condition of the waste management equipment.

8.4.17 Provision should be made for the prompt reporting and dissemination of information concerning the emergency or accidental release of radioactive substances in excess of recommended limits.

## Section 9

### Radioactive Waste Management

#### 9.1 General

9.1.1 The following safety principles should be adhered to in regard to radioactive waste:

- .1 A strategy should be developed and implemented for the management all types of radioactive waste on the FNPP. This strategy should be agreed by the Nuclear Regulatory Body in consultation with IRS and the Flag Administration.
- .2 The generation of radioactive waste should be prevented where possible or minimised in terms of the quantity and activity of the waste generated.
- .3 The accumulation of radioactive waste on the FNPP should be minimised.
- .4 Radioactive waste should be characterised, segregated and stored to facilitate safe and effective management
- .5 Radioactive waste should be stored in dedicated compartments/ spaces employing safe engineering practices as well as in a passively safe condition.
- .6 Radioactive waste should be processed into a passively safe state as soon as it is reasonably practicable to do so.
- .7 Records should be kept regarding the safe management of radioactive waste.

9.1.2 The design of the nuclear power plant and the associated parts of the FNPP should incorporate appropriate means for the safe collection, management, storage and eventual disposal of radioactive waste taking into account the operations of the FNPP. This should also take into account provision of access to facilities, lifting equipment and for packaging such radioactive waste.

9.1.3 The design of the nuclear power plant should be such as to minimize the production of radioactive waste as far as is reasonably achievable.

9.1.4 The design of the reactor plant should include adequate provisions for the control and treatment of the solid, liquid and gaseous radioactive waste produced during normal operation and following anticipated operational occurrences, to ensure that the radiological impact on the FNPP and its environment is within authorised limits and as low as is reasonably achievable.

9.1.5 The design and operation of the radioactive waste treatment and storage facilities should take account of the quantities and types of waste generated, the physical properties of waste and any hazards that could arise from it as mentioned below but not limited to the following:

- .1 Potential quantities of radioactive waste generated
- .2 Shielding and cooling requirements
- .3 Possible corrosive effects of certain radioactive liquids or gases
- .4 Detection of leaks

- .5 Presence and detection of combustible gases, such as hydrogen
- .6 Provisions to prevent the explosion of combustible gases or liquids and to mitigate its effect should it occur

9.1.6 The capacity of the solid, liquid and gaseous radioactive waste storage facilities should be suitable for the FNPP service and include an appropriate allowance for contingencies.

9.1.7 The capacity should be sufficient for all the radioactive waste generated during normal operation, abnormal operational occurrences and accident conditions.

9.1.8 The waste management facilities should be designed to prevent the uncontrolled release of radioactive waste to the environment.

9.1.9 On board facilities provided for the storage, processing, transportation and discharge of radioactive waste should be designed, constructed and installed, maintained and periodically inspected considering their safety implications to ensure that any uncontrolled release of radioactive substances to the environment or into other compartments of the FNPP is prevented.

9.1.10 Combustible wastes should be adequately protected against fire.

9.1.11 Handling and storage of radioactive waste, in quantities that could significantly contribute to personal doses received in the event of an accident (e.g. collision, fire, structural damage etc.), should be restricted to areas/spaces of the FNPP protected against collisions. Limited quantities of radioactive wastes may be carried outside these areas provided that they are properly packaged in containers approved by the statutory authorities.

9.1.12 No radioactive waste other than the FNPP's own treated waste should be stored on board.

## **9.2 Discharge of radioactive waste**

9.2.1 Discharge of radioactive waste (if any) should be in accordance with statutory requirements.

**Note:** This is not a classification requirement and is offered solely as a recommendation.

## **9.3 Management of Solid Radioactive waste**

9.3.1 Facilities should be provided on board the FNPP for the collection, treatment and storage of solid radioactive waste that has sufficient capacity for the volume and type of waste generated.

9.3.2 Discharge of solid and liquid waste to appropriate dockside facilities should be in accordance with statutory requirements. Under no circumstances should solid radioactive waste be discharged to the sea.

**Note:** This is not a classification requirement and is offered solely as a recommendation.

9.3.3 This should include all the sources of solid radioactive waste arising from the operation of the nuclear reactor including:

- .1 Ion exchange resins (where they are used).
- .2 Filters
- .3 Miscellaneous items such as contaminated clothing, tools and other items

9.3.4 Adequate cooling arrangements should be provided for the solid radioactive waste as appropriate.

9.3.5 Facilities should be provided for the transfer of solid radioactive wastes from the FNPP to a storage facility on the shore.

## 9.4 Management of Liquid Radioactive Waste

9.4.1 Facilities should be provided on board the FNPP for the collection, treatment and storage of liquid radioactive waste that has sufficient capacity for the volume and type of waste generated. The design of the plant should incorporate suitable means to keep liquid radioactive releases to the environment as low as reasonably achievable and to ensure that radioactive releases remain below the authorized limits.

9.4.2 Exposure of persons due to discharges to the environment should be as low as reasonably achievable.

9.4.3 This should include all the sources of liquid radioactive waste arising from the operation of the nuclear reactor including:

- .1 Primary and secondary coolant
- .2 Equipment and personal decontamination, laundry, sampling and other miscellaneous sources
- .3 Repair and maintenance work
- .4 Miscellaneous items (e.g. contaminated clothing, tools and other items)

9.4.4 Facilities should be provided to monitor the liquid radioactive waste in storage.

9.4.5 Adequate cooling arrangements should be provided for liquid radioactive waste treatment and storage facilities.

9.4.6 Facilities should be provided for the transfer of liquid radioactive wastes from the FNPP to a storage facility on the shore.

## 9.5 Management of Gaseous Radioactive Waste

9.5.1 Facilities should be provided on board the FNPP for the collection, treatment and storage of gaseous radioactive waste that has sufficient capacity for the volume and type of waste generated. This should include all the sources of gaseous radioactive waste arising from the operation of the nuclear reactor which may include the following but not be limited to:

- .1 Neutron activation of the primary coolant and its impurities (for water cooled reactors only).
- .2 Escape of gaseous and volatile fission products from defective fuel elements (for reactors with solid fuel elements only).
- .3 Direct neutron activation of the air of the containment structure

**Note:** This requirement should be specially considered for non-water cooled and small modular reactors

9.5.2 Means should be provided to control all discharge routes through which gaseous radioactive waste could be released into the environment external to the FNPP. Such discharge routes should consider the following but not be limited to:

- .1 Leakage from the primary coolant (for water cooled reactors only)
- .2 Venting of the primary circuit (mainly for water cooled reactors)
- .3 Venting of the waste tank gas spaces
- .4 Venting of the containment structure volume

**Note:** This requirement should be specially considered for non-water cooled and small modular reactors.

9.5.3 Discharge lines for gaseous radioactive waste to the environment should be equipped with an isolation capability to prevent inadvertent or uncontrolled releases.

9.5.4 Any discharge of gaseous radioactive waste should be in accordance with statutory requirements.

**Note:** This is not a Classification requirement and is offered solely as a recommendation.

9.5.5 Means should be provided to monitor the gaseous radioactive waste in storage.

9.5.6 Means should be provided for the transfer of gaseous radioactive wastes from the FNPP to a storage facility on the shore.

9.5.7 The cleanup equipment for the gaseous radioactive substances should ensure to keep radioactive releases below the authorized limits on discharges. Filter systems should be designed so that their efficiency can be tested, their performance and function can be regularly monitored over their service life, and filter cartridges can be replaced while maintaining the throughput of air.

## **9.6 Heating, Ventilation and Air Conditioning**

9.6.1 Ventilation systems with adequate filtration should be provided to:

- .1 Maintain the airborne concentration of radioactive material within specified limits.
- .2 Permit reactor containment structure purge capability
- .3 Prevent the uncontrolled spread of airborne contamination

9.6.2 Exhaust from the containment structure purge system and from the safety enclosure ventilation system should be through a monitored, alarmed and filtered route leading to a discharge point, so designed as to avoid contamination of normally inhabited areas and accumulation of radioactive materials in the discharge lines.

**Note:** This requirement should be specially considered for non-water cooled and small modular reactors.

9.6.3 The ventilation and filtration system for the containment structure should be independent of the systems serving any compartment outside the safety enclosure.

9.6.4 Exhaust air from controlled and supervised areas should be continuously monitored so that it is possible to pass such air through efficient filters capable of a high standard of separation.

## Section 10

### Surveys

#### 10.1 General

10.1.1 This Section specifies requirements for surveys of the FNPP. These requirements are in addition to those related to the nuclear reactor including its auxiliaries and components. The requirements of IRS Main Rules are applicable to surveys of the FNPP Hull, Machinery and Safety Systems. For mooring systems, the surveys should be in accordance with Chapter 5 of the *Rules and Regulations for Construction and Classification of Floating Offshore Units*.

10.1.2 This Chapter provides additional requirements for surveys during construction, surveys during commissioning and periodical surveys in so far as the scope of Classification is concerned. The requirements of the national nuclear regulatory body are applicable in so far as the inspections of the nuclear power plant (including the nuclear reactor, components and associated systems) are concerned. The potential overlap between the survey regimes for the marine and the nuclear components should be recognized and recorded in the boundary conditions document.

10.1.3 Surveys should be performed to ensure the following but may not be limited to:

- .1 materials and procedures used are of the requisite quality according to the design class of the component.
- .2 test results of material properties before and during manufacture comply with the specifications approved by IRS.
- .3 manufacturing processes comply with quality assurance procedures required to assure the intended performance and reliability of surveyed components and systems.
- .4 components and systems are manufactured and examined in compliance with drawings and specifications approved by IRS.
- .5 operation of components and systems complies with their specified functions, particularly the fundamental safety functions, as described in Section 2.
- .6 the FNPP and all systems essential to safety are maintained and continue to function properly throughout the operating life.

10.1.4 Surveys, tests and reviews of systems, components, structures and drawings, should be specified in accordance with the relevant safety class. An inspection and survey plan should be submitted to IRS and should describe details such as:

- .1 methods to be used
- .2 intervals between inspections
- .3 appropriate inspection authority
- .4 scope of inspections
- .5 procedures for corrective action

10.1.5 Where necessary for radiation safety, additional biological shielding, special test procedures and appropriate decontamination measures should be employed during surveys and tests.

10.1.6 The results of surveys and tests should be recorded, and copies of all reports should be kept on board for review. Survey and test reports should contain the following data:

- .1 the FNPP's name, IMO Number (if applicable), identifying numbers or letters, date and place of survey.
- .2 the systems, subsystems and components surveyed.
- .3 status of reactor operation.
- .4 the safety functions tested, including a description of the procedures and methods used.
- .5 test results, including malfunctions observed before and during the test and including a description of the observed state of the components or systems.
- .6 time under load and time of availability and equivalent information, if so required by the survey specification.
- .7 radiation and contamination conditions, if any, including special shielding provisions made or decontamination action taken.
- .8 requirements for survey repetition, where necessary.
- .9 special conditions of operation, maintenance or repair, resulting from the survey or imposed by IRS.
- .10 names of those conducting the tests and name of the surveyors and other authorities represented.

## **10.2 Surveys during construction**

10.2.1 The requirements of the Main Rules/ MODU Rules/ FOU Rules should be applied as relevant and applicable. IRS will carry out an initial survey of the facilities for construction of the floating nuclear power plant and if necessary, those facilities where the nuclear power plant and its auxiliaries are constructed.

10.2.2 Surveys during the construction should include a complete survey of the hull structure, machinery and equipment, the primary pressure boundary components, and components of safety systems.

10.2.3 Surveys should ensure that all machinery, electrical, structural, communication, radiation protection and other systems and equipment comply with the requirements of these Guidelines.

10.2.4 The containment structure, its safety systems and their support systems, should be tested for compliance with their intended safety functions in accordance with the procedures described in 10.1 and be pressure tested and tested for leaks to demonstrate that they meet the design requirements and the safety requirements as specified in the safety analysis report and in the licence conditions.

10.2.5 Testing should comply with all applicable classification and statutory requirements.

10.2.6 Pressure retaining, and other highly stressed components, should be tested in compliance with the following requirements:

- .1 Components of Safety Class-1 or Safety Class-2 should be pressure tested to a pressure suitably in excess of their design pressures so as to conform to the standards under which the components were designed. Material properties and temperature should be taken into account while determining test pressures

- .2 Components of Safety Class -3 should be pressure tested to a pressure suitably in excess of the design pressure in compliance with statutory requirements.
- .3 Subject to .1 and .2 above, components and systems retaining radioactive liquid or gaseous substances or deposits should be pressure tested to an overpressure in accordance with statutory requirements and be examined for gas and leak tightness. The sensitivity of the gas and leak detection methods used should be commensurate with the level of radioactivity to be retained.
- .4 Shafts, blades, bolts and other highly loaded items of machinery and equipment of Safety Class-1 should be subjected to tests equivalent to those required by IRS and rotating parts should be tested by overspeed tests.

10.2.7 Sensing elements, instruments and other components that must operate reliably under accident conditions, should be tested in accordance with the following requirements:

- .1 Prototype and periodic samples of a production run of such equipment should be tested under equivalent accident conditions of temperature, pressure, moisture, vibration and radiation
- .2 After completion of installation on board and prior to the reactor attaining initial criticality, the safety and reactor protection systems, including the radiation monitoring equipment control instrumentation, switch gear, controls and monitors, should be tested for satisfactory operation and accuracy. As far as is practicable, the operation of the sensing elements should also be checked.

10.2.8 Electrical and electronic equipment of the reactor safety systems and appliances for instrumentation, controls and switch gear should be type tested if of Safety Class 1 to 3 and should comply with the following requirements:

- .1 The specified accuracy of the sensing elements and the signal processing gear should be demonstrated by the manufacturer. Calibration of the nucleonic measuring channels in safety systems should be demonstrated
- .2 Proof of the quality and characteristics of the materials of pressure retaining items of instrumentation for Safety Class 1 and 2 should be provided. These constructional elements or components should be pressure-tested.

### 10.3 Surveys during commissioning

10.3.1 Surveys during the trials phase should cover the testing of all FNPP systems, including a complete pre-operational test of the NPP, core loading, initial power operation and sea trials.

**Note:** Approval of the overall trials programme should be listed in the boundary conditions document (see section 1.3).

10.3.2 Before core loading, the NPP should be examined in accordance with statutory requirements. Additionally, checks should be carried out to ensure:

- .1 the leak tightness of the circuits, at nominal pressure.
- .2 proper operation of instrument systems for measuring pressure, temperature, flow rate and liquid levels in the circuits, and
- .3 proper operation of relief and safety valves of the circuits.

10.3.3 After core loading, but prior to warming up the primary circuit, the requirements of 10.3.2.1 and 10.3.2.2 should again be checked, as well as:

- .1 physical/ chemical quality of the coolant to ensure that it is within acceptable parameters.

- .2 proper operation of main and emergency systems of electrical power.

10.3.4 During the testing phase preceding criticality, checks should be made to ensure:

- .1 proper operation of the reactivity control systems, including SCRAM.
- .2 proper operation of the nuclear measurement system and associated safety features.
- .3 proper operation of the health physics measurement equipment.
- .4 proper operation of auxiliary and emergency circuits.
- .5 containment structure and safety enclosure gas and leak tightness and proper functioning of automatic isolation provisions.
- .6 non-occurrence of reactor trip as a result of non-valid scram signals.
- .7 proper operation of the reactor protection systems.
- .8 accuracy of measurement instrumentation related to core safety.
- .9 proper switch-over to any standby unit of redundant systems.

10.3.5 During initial criticality and core physics testing, but before powering the core, it should be assured that the NPP and more generally, all the vessel's equipment have the availability required by the Safety Assessment. Amongst others, the following should be checked:

- .1 proper activation of the emergency core cooling systems including switch-over arrangements.
- .2 values of reactivity parameters and margins of subcriticality, in all appropriate conditions, to verify values declared in the Safety Assessment.

10.3.6 During initial power operation prior to sea trials, the following should be checked by means of low power tests:

- .1 proper operation of electrical power supplies and proper operation of the sequential transient from one connecting configuration to another.
- .2 effectiveness of the shielding against radiation from reactor and auxiliary circuits.
- .3 proper operation of equipment for measuring radioactivity in the Nuclear Power Plant circuits.
- .4 accuracy and proper operation of instruments measuring reactor power.
- .5 possible contamination of non-radioactive circuits.
- .6 measurement of the reactivity parameters and the subcriticality available margin in all appropriate conditions, to verify those values declared in the Safety Assessment.
- .7 proper switching of residual heat removal means from normal operational to alternative systems
- .8 provisions of effective reactivity and power control, sufficient to satisfy basic safety functions in 4.1.1.
- .9 proper operation of the emergency residual heat removal system.
- .10 provision of sufficient radiation control, registration and protection equipment to satisfy basic safety functions in 4.1.1.

10.3.7 During the sea trials phase, surveys and tests should be carried out as prescribed in the following:

- .1 Nuclear Power Plant and FNPP systems should be checked for safe and satisfactory operation under normal operating conditions. Items to be checked include the following:
  - a. proper operation of the NPP, due attention being paid to power transients, protracted full power operation and emergency power rate changes as applicable.
  - b. effectiveness of reactor poison override / control provisions.
  - c. appropriate values of fundamental physical parameters related to the safety of the reactor.
  - d. proper operation of electrical power supplies, using their primary energy from reactor plant and proper operation of the sequential transient from one connecting configuration to another.
  - e. proper operation of equipment for measuring radioactivity in the NPP circuits.
  - f. accuracy and proper operation of instruments measuring reactor power.
  - g. possible contamination of non-radioactive circuits.
  - h. restarting the reactor immediately following a random fast shutdown and after a period of low power operation.
  - i. ability to carry out in-service testing of the reactor Protection system, without loss of safety functions.

10.3.8 The Nuclear Power Plant should undergo trials at sea to prove that it will function in compliance with design requirements as declared in the Safety Assessment during any Plant States 1 or 2 situations, such as those involving the following:

- .1 relevant failure of any reactor or machinery active component;
- .2 trip of any single power conversion machinery during full power operation; and
- .3 failure of any Nuclear Power Plant system during switchover to standby systems

10.3.9 Following completion of sea trials, it should be demonstrated that:

- .1 Radioactivity is contained within designed compartments, and the reactor interfaces show no unintentional radioactive leakage
- .2 intentional releases of radioactive gaseous or liquid wastes can be controlled to permissible levels and are not ingested by the FNPP's air and sea inlets

## **10.4 Periodical Surveys**

10.4.1 The provisions of this sub-section supplement the periodical survey requirements of the Main Rules which relate to non-nuclear components of the hull, machinery and equipment.

10.4.2 The NPP and supporting hull structure should be periodically surveyed as follows:

- .1 the NPP may be surveyed in accordance with 10.4.6;

- .2 the hull structure in way of the nuclear reactor and containment structure supports, and the structure forming the collision protective structure, should be surveyed as required by 10.4.6;
- .3 periodical surveys of pressure-retaining components of the NPP should comply with the requirements of 10.4.6 and 10.4.7.

10.4.3 Upon request, IRS may consider performing continuous surveys in lieu of the periodical surveys in accordance with the requirements of such schemes. Individual parts/ components may require to be inspected more than once during a cycle.

10.4.4 Periodical or continuous surveys should not be unduly restricted by radiation and pressure vessels, and piping systems should, whenever practicable, be accessible for survey.

10.4.5 Hull structure in way of the nuclear and the collision protective structure should be surveyed annually. The survey should include surveys for significant deformations (if any) and diminutions in thickness of the shell and main structural members, if such inspections were not done at the last drydocking.

10.4.6 Periodical surveys should be carried out to ensure that the nuclear reactor plant continues to comply with specified safety functions and should include the following:

- .1 Engineer's logs of reactor operation, activity release reports, and periodic in-service test data should be examined for abnormal operation
- .2 Operation of the following safety functions should be demonstrated to the satisfaction of the attending surveyor:
  - a. Reactor protection.
  - b. Emergency core cooling (including supply systems).
  - c. Residual heat removal.
  - d. Integrity of activity flow paths.
  - e. Reactivity control.
  - f. Emergency electrical system under full load.
  - g. Waste management and release control.
  - h. Containment functions, except leak rate measurements of containment structure and safety enclosure (closure function, isolation functional).
  - i. Controlled area ventilation.

10.4.7 During demonstration of the safety functions required by .2 above, the support systems should also be surveyed by the Surveyor, while they are in operation.

**Note:** The periodic inspection programme of the NPP should be listed in the boundary conditions document (see section 1.3).

## 10.5 Special Surveys

10.5.1 In addition to the annual survey requirements in 10.4.6, each special survey of the NPP should include the following:

- .1 Thorough examination of the primary pressure boundary structure, pressure vessels and piping, and associated machinery and equipment.
- .2 The integral leak rate of the containment structure should be measured.
- .3 All systems of should be surveyed for confirming specified function.
- .4 Highly stressed parts of the primary pressure boundary and primary pressure boundary welds, including adjacent heat-affected areas, should be subjected to non-destructive surface and volumetric examination in order to quantitatively measure any flaws or cracks that may have developed or propagated.

10.5.2 During periods of core refuelling and on all practical occasions during repair work when the NPP is not in operation, the following surveys should be carried out:

- .1 surveys of double bottom spaces, tanks, pressure vessels, pipes and fittings, structures and foundations in the Nuclear Reactor Compartment.
- .2 surveys of shields.
- .3 surveys of the primary boundaries and functional checks of the core residual heat removal systems.
- .4 functional checks of all engineered safety systems, especially those repaired or renewed, and checking of the time required to scram the reactor.
- .5 surveys of internal parts of the nuclear reactor (after the core is refuelled).
- .6 where necessary, the cleaning of all tanks, pressure vessels, pipes and spaces of the reactor compartment from corrosion, sediment and other contamination.
- .7 leak testing of containment structure.

## 10.6 Occasional Surveys

10.6.1 In accordance with the procedures and intervals given in the Operating Manual and any other statutory requirements, trained personnel should check safety functions during operational service between periodical surveys. Testing should at least cover systems of Safety Class 1 and 2 and should be supervised by the appropriate engineer officer and recorded in accordance with the operating manual.

10.6.2 A survey, either general or partial should be performed every time an accident is reported, or a defect is discovered which affects or could have affected the safety of the FNPP or the efficiency or completeness of its radiation protection or other equipment, or whenever any important repairs or renewals are made. The survey should be such as to ensure that the necessary repairs or renewals have been effectively made, that the material and workmanship of such repairs conform in all respects to all applicable quality requirements, and that the renewed or repaired parts comply in all respects with these guidelines.

10.6.3 Where a component of the NPP is replaced, added or altered during the lifetime of the FNPP, the preservice examination requirements for the affected component should be complied with prior to resumption of service. This examination may be scheduled before or after the system leakage test.

## References

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- [10] International Atomic Energy Agency: Report of the International Nuclear Safety Advisory Group: INSAG 28: Application of the principle of defence in depth in Nuclear Safety to Small Modular Reactors

**End of the Guidelines**