GOVERNMENT OF INDIA

AERB SAFETY GUIDE

OPERATIONAL LIMITS AND CONDITIONS FOR NUCLEAR POWER PLANTS

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OPERATIONAL LIMITS AND CONDITIONS FOR NUCLEAR POWER PLANTS

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FOREWORD

Safety of public, occupational workers and the protection of environment should be assured while activities for economic and social progress are pursued. These activities include the establishment and utilisation of nuclear facilities and use of radioactive sources. They have to be carried out in accordance with relevant provisions of the Atomic Energy Act 1962 (33 of 1962).

Assuring high safety standards has been of prime importance since the inception of nuclear power programme in the country. Recognising this aspect, the Government of India constituted Atomic Energy Regulatory Board (AERB) in November 1983 vide standing order No. 4772 notified in the Gazette of India dated December 31, 1983. The Board has been entrusted with the responsibility to lay down safety standards and to frame rules and regulations in respect of regulatory and safety functions envisaged under the Atomic Energy Act of 1962. Under its programme of developing safety codes and guides, AERB has issued four codes of practice covering the following topics:

Safety in Nuclear Power Plant Siting

Safety in Nuclear Power Plant Design

Safety in Nuclear Power Plant Operation

Quality Assurance for Safety in Nuclear Power Plants

Safety guides are issued to describe and make available methods of implementing specific parts of the relevant codes of practice as acceptable to AERB. Methods and solutions other than those set out in the guides may be acceptable if they provide at least comparable assurance that nuclear power plants can be operated without undue risk to the health and safety of the plant personnel, general public and environment.

The codes and safety guides may be revised as and when necessary in the light of experience as well as relevant developments in the field. The appendics included in the document are considered to be an integral part of the document, whereas the footnotes and bibliography are to provide information that might be helpful to the user.

The emphasis in the codes and guides is on protection of site personnel and public from undue radiological hazard. However, for aspects not covered in the codes and guides, applicable and acceptable national and international codes and

standards shall be followed. Industrial safety shall be assured through good engineering practices and compliance with the Factories Act 1948 as amended in 1987 and the Atomic Energy (Factories) Rules, 1996.

This safety guide provides guidance on the aspects of operational limits and conditions for nuclear power plants.

The Guide has been prepared by the staff of AERB and other professionals. In drafting this guide, they have used extensively the relevant documents of the International Atomic Energy Agency (IAEA) developed under the Nuclear Safety Standards(NUSS) programme, specially the IAEA Safety Guide on Operational Limits and Conditions for Nuclear Power Plants (No. 50-SG-03).

Experts have reviewed this guide and AERB Advisory Committees have vetted it before issue. AERB wishes to thank all individuals and organisations who reviewed the draft and finalised the guide. The list of persons, who have participated in the committee meetings, alongwith their affiliations is included for information.

P. Rama Rao

(P.Rama Rao)
Chairman, AERB

DEFINITIONS

Acceptable Limits

Limits acceptable to Regulatory Body.

Accident Conditions

Substantial deviations from Operational States[1] which could lead to release of unacceptable quantities of radioactive materials. They are more severe than anticipated operational occurrences and include Design Basis Accidents and severe accidents.

Anticipated Operational Occurrences[2]

All operational processes deviating from normal operation which may occur during the operating life of the plant and which in view of appropriate design provisions, neither cause any significant damage to Items Important to Safety nor lead to Accident Conditions.

Approval

A formal consent issued by the Regulatory Body to a proposal.

Atomic Energy Regulatory Board (AERB)

An authority designated by the Government of India to enforce the rules promulgated under the relevant Sections of the Atomic Energy Act 1962, for the control of radioactive substances (section 16), special provisions to safety (section 17) and administration of the Factories Act 1948 (section 23).

Audit[3]

A documented activity performed to determine by investigation, examination and evaluation of objective evidence the adequacy of, and adherence to, Codes, Standards, specifications, established procedures, instructions, administrative or operational programmes and other applicable documents and the effectiveness of their implementation.

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1 Substantial deviation may be a major fuel failure, a Loss of Coolant Accident (LOCA) etc. Examples of Engineered Safety Features are: an Emergency Core Cooling System (ECCS), and containment.

2 Examples of Anticipated Operational Occurrences are loss of normal electric power and faults such as turbine trip, malfunction of individual items of control equipment and loss of power to main coolant pump.

3 The definitions refer to Quality Assurance activity as discussed in Quality Assurance Code and Guides.

Authorisation

See 'Regulatory Consent'.

Commencement of Operation[4]

The specific activity/activities in the commissioning phase of a Nuclear Power Plant towards first approach to criticality.

Commissioning[5]

The process during which structures, systems and components of a facility, having been constructed, are made operational and verified to be in accordance with design specifications and to have met the performance criteria.

Competent Authority

An officer or authority appointed or approved by the Government by notification for the purposes of the Rules promulgated under the Atomic Energy Act 1962.

Construction[5]

The process of manufacturing, testing and assembling the components of a facility, the erection of civil works and structures and the installation of components and equipment.

Decommissioning[5]

The process by which a facility is finally taken out of operation in a manner that provides adequate protection to the health and safety of the workers, the public and of the environment.

Documentation[3]

Recorded or pictorial information describing, defining, specifying, reporting or certifying activities, requirements, procedures and results.

Emergency Situation

A situation which endangers or is likely to endanger safety of the NPP, site personnel or the environment and the public.

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4 e.g. Fuel loading in case of Light Water Reactors and in case of Pressurised Heavy Water Reactors, heavy water addition with fuel already loaded.

5 The terms Siting, Construction, Commissioning, Operation and Decommissioning are used to delineate the five major stages of the authorisation process. Several of the stages may coexist; e.g. Construction and Commissioning, or Commissioning and Operation.

Examination[3]

An element of inspection consisting of investigation of materials, components, supplies or services, to determine conformance with those specified requirements which can be determined by such investigation.

Inspection[3]

Quality Control actions which by means of examination, observation or measurement, determine the conformance of materials, parts, components, systems, structures as well as processes and procedures with pre-determined quality requirements.

Items Important to Safety

The items which comprise:

(1) those structures, systems, equipment and components whose malfunction or failure could lead to undue radiological consequences at Plant or outside the Plant[6];

(2) those structures, systems and components which prevent Anticipated Operational Occurrences from leading to Accident Conditions;

(3) those features which are provided to mitigate the consequences of malfunction or failure of structures, systems or components.

Licensed Person

A person who has been licensed to hold certain Licensed Position of a NPP after due authorised procedure of certification by the AERB.

Licensed Position

A position, which can be held only by persons Certified by AERB or a body designated by it; e.g. Shift Charge Engineer, Assistant Shift Charge Engineer, Control Engineer, Assistant Shift Charge Engineer (Fuel Handling Unit) and Control Engineer (Fuel Handling Unit).

Normal Operation

Operation of a Plant or equipment within specified operational limits and conditions. In case of nuclear power plant this includes, start-up, power operation, shutting down, shutdown state, maintenance, testing and refuelling.

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6 This includes successive barriers set up against the release of radioactivity from nuclear facilities.

Nuclear Power Plant

A thermal neutron reactor or reactors together with all structures, systems and components necessary for safety and for the production of power, i.e., electricity.

Nuclear Safety

Protection of all persons from undue radiological hazard.

Objective Evidence

Term used in context of Quality Assurance, qualitative or quantitative information, record or statement of fact, pertaining to quality of an item or service, which is based on observation, measurement or test and which can be verified.

Operating Organisation[7]

The organisation so designated by responsible organisation and authorised by Regulatory Body to operate the facility.

Operating Personnel

Those members of Site Personnel who are involved in the operation of the NPP.

Operation.[5]

All activities following commissioning and before decommissioning performed to achieve in a safe manner the purpose for which an installation was constructed including maintenance.

Operational Limits and Conditions (OLC)

(See also technical specification)

Limits on plant parameters and a set of rules on the functional capability and the performance level of equipment and personnel, approved by the Regulatory Body, for the safe operation of the facility.

Operational Records

Documents such as instrument charts, certificates, log books, computer print outs and magnetic tapes, made to keep objective history of the NPP operation.

Operational States

The states defined under Normal Operation and Anticipated Operational Occurrences.

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7 Organisation structure and not individual names.

Plant Management

The members of Site Personnel who have been officially delegated responsibility and authority by the Operating Organisation for directing the operation of the plant.

Prescribed Limits

Limits established or accepted by Regulatory Body for specific activities or circumstances that must not be exceeded.

Qualified Person

A person, who having complied with specific requirement and met certain conditions, has been officially designated to discharge specific duties and responsibilities. [For example, Reactor Physicist, Station Chemist, and Maintenance Person of a Nuclear Power Plant are qualified persons]

Quality Assurance

Planned and systematic actions necessary to provide adequate confidence that an item or facility will perform satisfactorily in service as per design specifications.

Records

Documents which furnish objective evidence of the quality of items and activities affecting quality. It also includes logging of events and other measurements.

Regulatory Consent

It is a written permission issued by the Regulatory Body to perform the specified activities related to the facility. The types of consent are 'Licence', 'Authorisation', 'Registration', and 'Approval', and will apply depending upon the category of the facility, the particular activity and radiation sources involved.

Reliability

It is the probability that a structure, system, component or facility will perform its intended (specified) function satisfactorily for a specified period under specified conditions.

Responsible Organisation[8]

The organisation having overall responsibility for siting, design, construction, commissioning, operation and decommissioning of a facility.

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8 In the present context the Nuclear Power Corporation of India Limited (NPCIL) is the Responsible Organisation for Nuclear Power Plants in India.

Regulatory Body

See 'Atomic Energy Regulatory Board'

Safety

See 'Nuclear Safety'.

Safety Limits

Limits upon process variables within which the operation of the facility has been shown to be safe.

Safety Report

A document provided by the applicant or licensee to the Regulatory Body containing information concerning the facility, its design, accident analysis and provisions to minimise the risk to the public and to the site personnel.

Safety Critical systems (Safety Systems)

Systems important to safety, provided to assure, under anticipated operational occurrences and accident conditions, the safe shutdown of the reactor (Shutdown System) and the heat removal from the core (Emergency Core Cooling System), and containment of any released reactivity (Containment Isolation System).

Severe Accidents

Nuclear Power Plant conditions beyond those of the Design Basis Accidents causing significant core degradation.

Site

The area containing the facility defined by a boundary and under effective control of facility management.

Site Personnel

All persons working on the site, either permanently or temporarily.

Siting

The process of selecting a suitable site for a facility including appropriate assessment and definition of the related design bases.

Specification

A written statement of requirements to be satisfied by a product, a service, a material or process indicating the procedure by means of which it may be determined whether specified requirements are satisfied.

Surveillance[9]

All planned activities namely monitoring, verifying, checking including in-service inspection, functional testing, calibration and performance testing performed to ensure compliance with specifications established in a facility.

Technical Specifications for Operation

A document submitted on behalf of or by the responsible organisation covering operational limits and conditions, surveillance and administrative control requirements for the safe operation of the facility and approved by Regulatory Body.

Ultimate Heat Sink

The atmosphere or a body of water to which residual heat is ultimately transferred during Normal Operation, Anticipated Operational Occurrences or Accident Conditions.

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9 This includes activities performed to assure that provisions made in the design for safe operation of the NPP continue to exist during the life of the plant.

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1. INTRODUCTION

1.1 General

1.1.1 This Safety Guide on Operational Limits and Conditions for Nuclear Power Plants (AERB/SG/O-3) supplements the provisions of the Code of Practice for Safety in Operation of Nuclear Power Plants (AERB/SC/O). It identifies the main objectives and responsibilities relating to safe operation of NPPs.

1.1.2 The principles of Operational Limits and Conditions (OLCs) for Safe Operation of NPPs are briefly enunciated in Section 7 of AERB/SC/O. This Safety Guide (AERB/SG/0-3) elaborates on those principles and recommends procedures for implementing them and for development of technical specification for operation of NPPs.

1.1.3 For an NPP to be operated in a safe manner, the provisions made in the final design shall be reflected in limitations on plant operating parameters and in the requirements on plant equipment and personnel.

1.2 Objectives

1.2.1 This Safety Guide has the following objectives:-

(i) To focus on the need to develop, a set of operational limits and conditions for the NPP, before it is licensed to operate under the responsibility of the operating organisation[1];

(ii) To emphasize to the Plant Management that instructions and operating manuals for the NPP shall be consistent with operational limits and conditions approved by the Regulatory Body; and

(iii) To highlight the requirement for the operating personnel to ensure that the plant operation is carried out in accordance with Operational Limits and Conditions as contained in the Technical Specifications for Operation issued by the Regulatory Body specifically for the respective power plant.

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1 Where operating organisation is not defined, these functions are the responsibility of Responsible Organisation(RO) or Plant Management as delegated by R.O.

1.3 Scope

1.3.1 This Safety Guide covers the concept of operational limits and conditions as well as the guidelines on their content as applicable to NPPs based on thermal neutron reactors.

1.3.2 It also covers the responsibilities of the operating organisation on this subject such as establishing OLC, surveillance, compliance, modifications and documentation.

1.3.3 The Safety Guide includes guidelines on both the technical and administrative aspects involved in operational limits and conditions.

1.3.4 Surveillance requirements are covered in the Safety Guide on Surveillance of Items Important to Safety in NPPs, AERB/SG/O-8. For the organisational requirement Safety Guide on Management of NPPs for Safe Operation, AERB/SG/O-9 may be referred.

2. CONCEPT OF OPERATIONAL LIMITS AND CONDITIONS

2.1 General

2.1.1 The operational limits and conditions shall be directed to:

(a) the prevention of situations which might lead to accident conditions

(b) the mitigation of the consequences of such accident conditions should they arise.

2.1.2 As regards 2.1.1 (a), the operational limits and conditions shall specify safety requirements for all modes of normal operation such as starting up, power production, shutting down, shutdown, maintenance, testing and refueling and also for anticipated operational occurrences.

2.1.3 As regards 2.1.1 (b), the operational limits and conditions shall define requirements to ensure that safety systems including engineered safety features will perform the functions as required in accident conditions.

2.2 Operational Limits and Conditions (OLCs)

2.2.1 The operational limits and conditions shall take into account the technical aspects related to the operation of the nuclear power plant, including the functioning of safety systems. Safe operation depends on people as well as on equipment; therefore operational limits and conditions shall also cover actions to be taken and limitations to be observed by the operating personnel. Wherever an operator action is called for, operator comprehension and response time should be considered.

2.2.2 The technical aspects of the operational limits and conditions cover limitations as well as requirements to perform intended functions of all structures, systems and components important to safety of the nuclear power plant.

2.2.3 With regard to operating personnel, the operational limits and conditions include those principal requirements for surveillance and corrective or complementary actions to supplement equipment functions involved in operational limits and conditions. Such actions are performed by personnel responsible for operation within prescribed limitations to ensure safe operation of the plant. Some operational limits and conditions may involve combinations of automatic functions and actions by personnel.

2.3 Classification

2.3.1 Operational limits and conditions shall be established and may be classified as under, according to their functional intent.

(a) Safety Limits (SL)

(b) Limiting Safety System Settings (LSSS)

(c) Limiting Conditions for Operation (LCO)

(d) Surveillance Requirements

It should be understood that operational limits and conditions form a logical system in which the classes listed above are closely inter-related and in which the safety limits express the ultimate boundary of safe conditions.

2.3.2 **Safety Limits** are limits on process variables within which the operation of the nuclear power plant has been shown to be safe. In case of violation of one or more of them, unacceptable degradation of integrity of items important to safety and/or unacceptable release of radioactivity are likely to occur. If safety limits are exceeded, the nuclear reactor shall be immediately shutdown and maintained in cold depressurised state. The reactor shall be restarted only after review and approval of the Regulatory Body.

Automatically actuated engineered safety features are also provided in the design to mitigate the consequences of accident conditions. These are actuated at a specified setting to ensure that safety limits are not exceeded.

2.3.3 **Limiting Safety System Settings** are the instrument set points for actuation of appropriate automatic protective devices which are intended to initiate action to prevent a safety limit being exceeded and to cope with anticipated operational occurrences.

2.3.4 **Limiting Conditions for Operation** are intended to ensure safe operation and to avoid reaching safety system settings as well as to ensure readiness for performing necessary functions in the event of an accident. These include limits on operating parameters These LCOs specify the requirements of minimum operable equipment of various systems, minimum staff required and the prescribed actions to be taken by the operating staff.

This class of LCOs covers actions necessary to ensure that the frequency and magnitude of occurrences affecting normal operation are minimised. This includes operating limits for parameters important to safety such as chemical composition of working media, their radioactivity content, and discharge limits of radioactive material to the environment. LCOs are chosen such that the required safety system effectiveness is not impaired.

The requirements of operable safety-related equipment should take into consideration the provisions contained in the design assessment of redundancy, the reliability of the equipment, and the period over which a unit of equipment may be inoperable before plant safety is adversely affected.

2.3.5 Surveillance Requirements

Surveillance requirements, necessary to ensure compliance with the operational limits and conditions, cover periodic checks, tests, calibrations and inspections of safety systems.

Such surveillance should verify the state, operability, performance and correct settings or indications of equipment, components or processes involved in the operational limits and conditions under question and should indicate the surveillance frequency for ensuring required degree of reliability.

2.4 Operational Limits

It is important that the operational limits and conditions are meaningful to the operating personnel. For this purpose, these should be stated in a manner that they are defined by values of parameters measurable directly from the plant instrumentation. In cases where this is not possible, the relevant parameter values have to be computed from the measured plant data. For such cases, the computational methodologies should be worked out and validated. For example, the operational limits required to maintain adequate heat transfer are arrived at based on calculations of the plant operating parameters such as core power, core power distribution/heat flux, core flow, core flow distribution, fuel temperature etc. Co-relation between observed values of parameters and the operational limit should also be established where feasible. This is illustrated in Appendix-I.

3. CONTENTS OF OPERATIONAL LIMITS AND CONDITIONS

3.1 General

3.1.1 The concept of safety limits is based on the prevention of situations leading to releases of radioactive materials from the plant beyond acceptable limit.

3.1.2 No significant releases of radioactive materials from the fuel can occur if the cladding integrity is maintained. An essential factor in maintaining fuel cladding integrity is adequate cooling of the fuel. In this regard, keeping the reactor cooling system pressure boundary intact is most important. This prevents loss of coolant and the resulting degradation of cooling effectiveness. The fuel cladding, coolant system pressure boundary and containment building provide barriers against release of radioactive materials.

3.1.3 Analyses of nuclear power plants with thermal reactors of different types have shown that the integrity of fuel cladding and pressure boundary barriers, and thus the safety, can be ensured if the operation of the plant is maintained within the bounds of the safety limits described in sub-section 3.2. Other important aspects of safe operation are the settings of safety systems (see sub-section 3.3), the limits and conditions for normal operation (see sub-section 3.4), and the surveillance programme (see sub-section 3.5).

3.1.4 It should be emphasised that the items listed in sub-sections 3.2 to 3.4 represent typical requirements which practices have shown to be very useful in establishing agreement on operational limits and conditions between the Regulatory Body and the operating organisation. Some additional requirements may be established by the operating organisation for implementing its responsibility. Any such additional requirement such as fuel power rating, rate of power rise, and fuel burn-up should be included in the operating and maintenance instructions.

3.2 Safety Limits (SL)

3.2.1 General

Safety limits are based on the best conservative design estimates. Basic safety limits are the fuel cladding temperature to maintain the physical integrity of the fuel and the coolant pressure to maintain the physical integrity of coolant channels, reactor pressure vessel and/or requirement within the coolant pressure boundary.

3.2.2 Fuel and Fuel Cladding Temperatures

The temperatures of the fuel and fuel cladding shall be limited to values which can ensure that the extent of failures, if any, is acceptable. The safety limits should be normally stated as the maximum acceptable values of fuel and/or cladding temperatures and in case of BWRs, the Minimum Critical Heat Flux Ratio (MCHFR).

3.2.3 Reactor Coolant System Pressure

Safety limits for the reactor coolant system pressure shall be stated in relation to design pressure and system temperature.

3.3 Limiting Safety System Settings (LSSS)

3.3.1 General

LSSS should provide sufficient margin below SL and are selected for the parameters included in safety limits and for other parameters or a combination of parameters which could contribute to pressure or temperature transients. Exceeding some of these settings will cause the reactor to be tripped to suppress a transient.

Other than LSSS, there may be other safety system settings, which when exceeded will result in other automatic actions, to prevent safety limits from being exceeded. Some of the safety system settings are provided to initiate operation of engineered safety features. These features limit the course of anticipated transients in such a way that either safety limits are not exceeded or the consequences of postulated accidents are mitigated.

3.3.2 Typical Considerations Requiring Limiting Safety System Settings

The following are typical considerations, for which limiting safety system settings would be required as applicable:

(a) neutron flux and its distribution (start-up, intermediate and power ranges);

(b) rate of change of neutron flux;

(c) reactivity protective device positions;

(d) coolant channel outlet temperature;

(e) reactor coolant temperature at outlet header for PHWR;

(f) reactor coolant system pressure (outlet header);

(g) reactor pressure vessel or pressuriser water level;

(h) reactor coolant flow;

(i) primary coolant circulation pump trip;

(j) emergency coolant injection;

(k) steam generator water level;

(l) loss of normal electrical power supply;

(m) steam line radiation level; and

(n) containment pressure.

In addition there are other settings important to safety which needs to be addressed, such as:

(a) emergency coolant injection;

(b) settings provided to initiate steam line isolation, turbine trip and feed water isolation;

(c) reactor building radiation and building atmospheric contamination level; and

(d) settings provided to initiate startup of containment spray system, containment cooling and isolation systems.

The actions to be initiated as described in sub-section 3.3.1 for the items listed above may vary according to reactor type and design and some of the settings may not be applicable. For particular reactor types, additional

parameters may be described in the safety report, for which safety system settings shall be specified.

3.4 Limiting Conditions for Normal Operation (LCNO)

3.4.1 General

Limiting conditions for normal operation are established to provide acceptable margins between the normal operating parameters and the established limiting safety systems settings. They include the pre-requisite of a system configuration and operating personnel, i.e.minimum operable equipment, minimum staffing and prescribed actions to be taken by the operating staff.

Appropriate alarms are usually provided to enable the reactor operating personnel to initiate corrective actions before limiting safety system settings are reached.

Operability[2] requirements shall state, for the various modes of normal operation, the number of systems or components which shall be either in the operating or in the standby condition. Where operability requirements cannot be met to the extent intended, the actions to be taken, such as power reduction or reactor shutdown, shall be specified. Operability requirements for start-up after outages should be more stringent than those permitted for operational flexibility during power operation. Safety system equipment required to be operable for start-up should be specified. When it is necessary to remove a component of a safety system, redundant channels of safety system shall continue to be effective in accordance with design provisions.

The items discussed in the remainder of sub-section 3.4 are those for which limiting conditions for normal operation are generally required. It must be recognised that for a particular plant design, other limits may be required to ensure that all parameters included in the design and safety analysis are adequately controlled. Similarly, the stated limiting conditions are not always absolute, and when they cannot be adhered to, the actions or measures to be taken should be specified. These include, in appropriate cases, a time limit within which corrective actions must be taken.

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2 A system or component shall be considered operable when it is capable of performing its intended function when called upon to do so.

3.4.2 Reactor Coolant System Temperature

Limits of coolant temperature (maximum or minimum) and location shall be stated for the various modes of normal operation to ensure that specified safety limits of core parameters are not exceeded and to ensure that temperatures affecting coolant system integrity are maintained within appropriate bounds.

Warm-up/cool-down rates of PHT as well as secondary system and corresponding permissible cycles including emergency cool-down rate should be stated.

3.4.3 Reactor Coolant System Pressure

Limits on permissible reactor coolant system pressure shall be stated for the various modes of normal operation. For some purposes, e.g. in order to take account of limitation in material properties, these operational limits shall be stated in conjunction with the parameters such as temperature or coolant flow. In such cases, the relations shall be stated clearly and any curves or calculational techniques required to ensure that permissible conditions are not exceeded shall be provided.

Similarly, special requirements shall be stated where applicable. Selection of limits shall be made so that the initial conditions assumed for various accident analyses are not exceeded and the integrity of the primary coolant system is maintained.

3.4.4 Reactor Power

Limits for reactor power shall be established with due consideration to the neutron flux distribution, in order to ensure that the fuel temperature or heat flux limits will not be exceeded. In PHWR, additionally the reactor power shall be controlled by the coolant channel outlet temperature monitoring system so as to be within the fuel cladding limiting temperature.

3.4.5 Reactor Coolant Chemical Quality

In addition to pressure and temperature limitations mentioned, limits shall be stated for coolant chemical parameters; for instance, in water-cooled reactors, conductivity, pH value, oxygen content and impurities such as chloride and fluoride are important.

3.4.6 Pressure Relief and Safety Valves

Operability requirements shall be stated regarding the number of safety and/or relief valves required for the reactor coolant system. For direct-cycle boiling water plants, this system includes steam system relief and safety valves. Pressure settings for valve actuation shall be stated. These values shall be selected such that system integrity is maintained under all operational states.

3.4.7 Emergency Core Cooling Systems

Operability requirements for various systems used for emergency core cooling shall be stated. These shall include valve operability, adequacy of coolant injection and circulation, integrity of piping system, and specified limits on minimum quantities of fluids for all systems relied upon for emergency core cooling.

These operability requirements shall cover all provisions necessary to cope with relevant accidents analysed in the safety report. In particular, to ensure continuous availability of these systems, operability requirements shall also be stated for emergency power supply systems and other auxiliary systems such as equipment cooling systems and ventilation systems. The long-term capability of these emergency systems after the occurrences shall also be considered and specified to ensure that release of radioactive substances to the environment is below allowable limits.

3.4.8 Moderator and Cover Gas System

As appropriate, limits regarding moderator temperature, chemical parameters and levels shall be stated. Limits regarding permissible concentrations of explosive gas mixtures in the cover gas shall also be stated. In this regard, operability requirements for on-line process monitoring equipment shall be specified.

3.4.9 Steam Generators

Operability requirements consistent with those described in the safety report shall be stated for steam generators. These requirements shall include operability of emergency feed water systems and of safety and isolation valves of the steam system, as well as satisfactory water quality and specified limitations on water level.

3.4.10 Reactor Coolant System Leakage

In BWR, permissible leakage limits shall be such that coolant inventory can be maintained by normal make-up systems and the system integrity can be maintained to the degree specified in the safety report. In establishing leakage limits, consideration shall be given to the permissible limits of contamination of the environment or of secondary systems by the leaks. Operability requirements shall be stated regarding reactor coolant leakage detection or measuring systems.

3.4.11 Reactor Coolant Radioactivity

Limits regarding permissible specific activities of fission products in the reactor coolant shall be stated to ensure the protection of personnel and the environment as well as to provide a measure of fuel integrity as discussed in the safety report.

3.4.12 Ultimate Heat Sink

The ultimate heat sink in once-through open loop cooling systems usually 's the river, lake or sea from which coolant water for equipment and condensers is drawn. In closed loop systems, dry or wet cooling towers are also used with atmosphere as the actual heat sink. As atmospheric conditions can have seasonal variation, limitations on power production levels consistent with the cooling capability of these sinks for the minimum required duration shall be specified.

3.4.13 Negative Reactivity Requirements

In the new standardised design of PHWR NPP without provision for moderator dumping, there shall be two independent and effective reactor shutdown systems. Each reactor shutdown system shall have adequate negative reactivity available in the reactivity control devices such that the degree of sub-criticality specified in the safety report can be reached immediately after shutdown from any operational state and relevant accident conditions so that reactor shutdown is completed and maintained in safe shutdown state.

To maintain the specified degree of sub-criticality for an indefinite period of time after shutdown, additional means as provided in the design may be used (for PHWR), e.g. the use of borated heavy water, or other neutron poisons where the compensation for temperature, xenon or other transient reactivity effects cannot be achieved by normal reactivity control devices unlike in BWRs.

Before any start-up of the reactor, availability of independent shutdown devices with specified negative reactivity shall be ensured.

3.4.14 Reactivity Coefficients

For BWR,where the safety report indicates the need, limits shall be stated for the reactivity coefficients for different reactor conditions to ensure that the assumptions used in the accident and transient analyses remain valid through each fueling cycle.

3.4.15 Reactivity Control Logic

Special reactivity control logic, or control rod and/or absorber rod patterns, together with control rod reactivity worths shall be stated where necessary to ensure that specified limitations regarding permissible flux differences, power peaking factors and power distribution for various modes of normal operation are met. Proper control of flux distributions shall ensure that the limiting fuel temperatures and heat flux and the initial conditions considered in the accident analyses are not exceeded. Where appropriate, proper calculational methods or measuring techniques shall be provided to enable the reactor operator to determine compliance.

3.4.16 Positive Reactivity Insertion Rates

Positive reactivity insertion rate limits shall be stated and compliance ensured either by reactivity system logic or by special limitations to be observed by operating personnel to avoid reactivity-related accident conditions which might lead to excessive fuel temperatures.

3.4.17 Reactor Core Neutron Flux Monitoring

Instrumentation requirements for adequate neutron flux monitoring for all reactor power levels including startup and shutdown conditions shall be stated. These may include stipulations on the use of neutron sources for providing the necessary minimum neutron flux level and on the sensitivity of neutron detectors.

3.4.18 Reactivity Control Devices

Operability requirements, including redundancy or diversity requirements described in the safety report, for reactivity control devices and their position indicators, shall be stated for various modes of normal operation. These requirements shall comply with sub-section 3.4.15 and meet the negative reactivity requirements in accordance with sub-section 3.4.13.

These operability requirements shall specifically define the proper sequence and the actuation and insertion times for reactivity control devices. Reactivity control device operating times shall be consistent with design intent.

The number of reactivity devices that can be removed for maintenance at a time with reactor in shutdown state should be specified, taking into account the stipulated sub-criticality margin. For reactivity devices freshly installed, the negative reactivity worth specifications for each device should be stipulated. Also, qualification tests to meet the reactivity insertion time on demand for regulation/protection should be specified.

3.4.19 Reactivity Differences

Limits on permissible reactivity differences between predicted and actual critical configurations of reactivity control devices shall be stated, and conformance verified during initial criticality, after every major refuelling, and at specified intervals. The cause of significant differences shall be evaluated and necessary corrective actions taken.

3.4.20 Liquid Poison Systems

The following should be specified for liquid poison system:

- Parameters such as neutron poison material concentration, pH and temperature limit affecting the solubility of the poison;
- Peasures to ensure timely detection and correction of deviations from the limits specified for poison concentration;
- Operability requirements to ensure proper actuation and functioning of components associated with liquid poison systems;
- Alternate means of achieving subcritical margin during any maintenance work on liquid poison system's components.

3.4.21 Reactor Protection and Other Safety System Instruments

Operability requirements for reactor protection and other safety system instrumentation and logic, together with limits on response times, instrument drift and accuracy, where appropriate, shall be stated. Interlocks required by the safety report shall be identified and appropriate operability requirements stated.

3.4.22 Seismic Monitors

Where applicable, operability requirements for seismic monitoring instrumentation shall be stated. Settings shall be established for alarms. The number of devices specified shall be sufficient to ensure that the required automatic action is initiated at specified limits.

3.4.23 Supplementary Control Points, Instrumentation and Control

Where additional remote shutdown instrumentation and control are provided in the plant design to account for the possible loss of habitability of the main control room, the monitoring requirements for essential items (e.g. temperature, pressure, flow and neutron flux) shall be stated to permit the plant to be shutdown and maintained in a safe condition from a location outside the main control room.

3.4.24 Electrical Power Systems

Requirements for availability of electrical power sources shall be stated for all operational states. These include: off-site sources, on-site standby

power generation (diesels, gas turbines, including associated fuel reserves), batteries, MG sets, inverters and associated control, protection, distribution and switching devices. The operability requirements shall be such that sufficient power will be available to supply all safety-related equipment required for the safe shutdown of the plant and for the mitigation and control of accident conditions. The operability requirements shall determine the necessary power, redundancy of supply lines, maximum permissible time delay, and necessary duration of emergency power supply.

3.4.25 Fuel Handling

Operational requirements and procedures shall be stated for fuel and absorber handling. These shall include limits on the quantity of fuel which can be handled simultaneously and, if required, on temperature and decay heat of the irradiated fuel. Consideration shall be given to the prevention of movements of heavy equipment, such as the fuel shipping cask over the stored irradiated fuel. If appropriate, the operability of handling equipment shall be stated.

Provision shall be made for monitoring the core reactivity during fuel loading or refuelling operations to ensure that reactivity requirements are met. The procedures and instrumentation required for such monitoring shall be specified.

To ensure that operations which might give rise to power excursions or radiation hazards are not undertaken during fuel movements, requirements for communication between the fuel handling personnel and the operating personnel in the control room shall be stated.

3.4.26 Irradiated Fuel Storage

For BWR/enriched fuel, the conditions for irradiated fuel storage shall be stated and shall include: minimum cooling capability of the spent fuel cooling system and minimum water level above the fuel; the prohibition against storage of fuel in any position other than that designated for irradiated fuel; the minimum storage reserve capacity; and the appropriate reactivity margins to guard against criticality in the storage area.

Appropriate radiation monitoring shall also be specified for the irradiated fuel storage area. Adequate record for the irradiated fuel in the storage bay shall be maintained.

3.4.27 New Fuel Storage

For BWR, the criteria for new fuel storage shall be stated. Any special measures to avoid criticality of new fuel during handling or storage shall be stated. When required, fuel enrichment/depletion shall also be verified before insertion into the core.

3.4.28 Failed Fuel Detection

Where on-line measurement of coolant activity is used to monitor fuel cladding integrity during operation, the minimum provisions for detection and, where appropriate, identification of failed or suspect fuel shall be stated.

3.4.29 Core Verification

For BWR, after any core alteration, the location of fuel and other in-core components shall be confirmed in accordance with a written procedure, to ensure that every item is located in the correct place.

3.4.30 Radiation Monitoring Instrumentation

Operability requirements for radiation monitoring instrumentation, including effluent monitoring, shall be stated. It is necessary that these requirements ensure that appropriate areas and release paths are adequately monitored in accordance with radiological protection and requirements of Regulatory Body and that alarm or appropriate action is initiated when the prescribed radiation or activity limit is exceeded.

3.4.31 Ventilation Systems

Where applicable, appropriate limits shall be established on ventilation system operability where such systems have been provided for controlling airborne radioactivity within stated limits or for support of a safety system.

3.4.32 Ventilation of Secondary Containment

Where secondary containment is provided, it shall be ventilated and kept under appropriate negative pressure as described in the safety report to ensure that any possible direct leakage would remain below the value assumed. Appropriate limits in terms of pressure or leakage rates shall be stated.

3.4.33 Containment Systems

Operability requirements for containment systems shall be stated. Permissible leakage rates shall be specified. Equipment for which operability and conditions shall be stated include: isolation valves, vacuum breaker valves; actuation devices; filtration, cooling, dousing and spray systems; combustible gas control and analysing systems; venting and purging systems; and associated instrumentation. The operational conditions specified shall be such that the release of radioactive materials from the containment system will be restricted to those leakage paths and rates assumed in the accident analyses. Precautions for access control shall be specified to ensure that the effectiveness of the containment system is not impaired.

3.4.34 Plant Staffing

The plant personnel required to be on duty for various operational states shall be specified and shall be sufficient to implement the required emergency procedures. The minimum staffing required for the control room and field jobs shall be stated.

3.4.35 Reactor Restart

After any reactor trip, the cause of the trip shall be ascertained and evaluated to the extent necessary to provide assurance that it is safe to restart the reactor. If limits and conditions for normal operation have been exceeded, the cause should be investigated.

3.4.36 Man-induced Events and Extreme Natural Phenomena

Requirements should be stated for assessment and inspection of the nuclear power plant systems for possible damage after man-induced

events (such as fire, air-plane crash, pressure waves, and toxic and corrosive gases) and after extreme natural events (such as cyclones/storms, earthquakes and floods) before resumption or continuance of power operation.

3.4.37 Fire Prevention, Detection and Fighting

Limits on the availability and operability of the systems as applicable should be specified.

3.5 Surveillance Requirements

3.5.1 Surveillance requirements shall be stated for structures, systems and components for which limiting safety system settings and limiting conditions for normal operation have been specified. These requirements shall include, as appropriate, testing, calibration monitoring or inspection, to provide assurance that stated operational limits and conditions are met.

3.5.2 Requirements of surveillance frequencies shall be as per technical specification for operation and station policy for operation for the respective NPPs.

4. RESPONSIBILITIES OF THE OPERATING ORGANISATION[3]

4.1 Development of the Operational Limits and Conditions

4.1.1 The operating organisation shall be responsible for the development of operational limits and conditions and shall submit these to the Regulatory Body for assessment and approval before commencement of operation.

4.1.2 The operational limits and conditions shall be based on the safety analysis of the individual plant and its environment in accordance with the provisions made in the final design taking into account results of commissioning tests. the specification, basis and applicability of each of the OLCs shall be stated.

4.1.3 The operational limits and conditions should normally be developed in consultation with designers well before commencement of the operation to ensure that adequate time is available for assessment and approval by the Regulatory Body. Special arrangements may be established with the Regulatory Body for certain limits and conditions to be approved at a later time where their use is not required for initial operation.

4.2 Modification and Review

4.2.1 A procedure to be followed for modifications to the operational limits and conditions shall be established. The modifications to operational limits and conditions shall not be implemented until they have been reviewed and approved by the Regulatory Body.

4.2.2 The operational limits and conditions shall be reviewed during the operating life of the plant in the light of experience and technological developments and the operating organisation shall introduce the appropriate modifications in accordance with established procedures.

4.2.3 Operating Organisation shall be responsible for identifying the necessity for and initiating review of modifications to the operational limits and conditions.

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3 Please see footnote on page 1.

4.2.4 Review procedure should include the following aspects:

(a) subject to be reviewed;

(b) establishment of the responsibility and authority for review;

(c) mechanism for initiating review activities;

(d) provision for the use of specialists;

(e) mechanism for reaching decisions;

(f) provision for ensuring that personnel responsible for review have adequate expertise; and

(g) what records of the reviews are to be kept.

4.2.5 The evaluation and reporting of anticipated operational occurrences constitute an important source of information in determining whether modifications to the operational limits and conditions are required.

4.3 Compliance with Operational Limits and Conditions

4.3.1 The plant management has the primary responsibility to ensure that the operational limits and conditions are complied with. To fulfil this responsibility, relevant controls shall be established.

4.3.2 Procedures to be followed in the event of unusual occurrences shall be mutually agreed between the operating organisation and the Regulatory Body. These procedures shall state the criteria to be used as the basis for selecting those occurrences that shall be reported to the Regulatory Body; they shall also include a classification of deviations indicating those which require permission of the Regulatory Body for subsequent plant start-up.

4.3.3 The operating organisation shall conduct audits to verify compliance with the operational limits and conditions (see AERB/SG/QA-5).

5. DOCUMENTATION

5.1 Appropriate documentation of nuclear power plant operation is necessary to provide objective evidence of compliance with operational limits and conditions and to make sure that information which may be necessary for evaluating or investigating any deviations from an operational limit or condition is available. A typical list of documents to be maintained by stations is given in Appendix-II.

5.2 Station documents shall be maintained in a safe manner for designated periods as applicable for permanent (about 5 years) and temporary records by the station, as specified in the Station Policy for Operation and AERB Safety Guide, AERB/SG/QA-5 Annexure-II.

APPENDIX - I

ILLUSTRATION OF INTER-RELATIONSHIP BETWEEN SAFETY LIMIT, LIMITING SAFETY SYSTEM SETTING AND LIMITING CONDITIONS FOR OPERATION.

I.1 Introduction

I.1.1 General

I.1.1.1 Figure 1 is provided to explain some of the terms used in this Guide. It illustrates the inter-relationship between a safety limit, a limiting safety system setting and limiting condition for normal operation.

I.1.1.2 For clarity, the example given in Fig.1 illustrates only the case where the critical parameter of concern is the fuel cladding temperature. The different types of disturbance which may be experienced by this cladding temperature are shown.

I.1.1.3 It has been assumed in Fig.1 that correlation has been established in the safety analysis between a monitored parameter (in this case, coolant temperature) and the maximum fuel cladding temperature for which a safety limit has been established. The analysis would have shown that the actuation of the safety system by the monitored coolant temperature at the safety system setting prevents any fuel cladding temperature reaching the safety limit value beyond which significant release of radioactivity from the fuel may occur.

I.1.2 Range of Steady State Operation

The monitored parameter is kept within the steady state range by the regulating system or by the operator in accordance with operating instruction.

I.1.3 Range of Load Transients (Curve No.1)

I.1.3.1 The monitored parameters may go above the steady state range, as a result of, for example, load changes, despite the control system or operator action.

I.1.3.2 The upper limit of this range does not go beyond the relevant limiting safety system settings.

I.1.4 Limiting Conditions for Normal Operation

Limiting conditions for normal operation may be set at any level within the range of steady state operation and the limiting safety system settings for different system parameters to meet operating requirements as approved by the Regulatory Body.

I.1.5 Range of Anticipated Operational Occurrence (Curve No.2)

Owing to malfunction of control system, or due to operator error or, for any other reasons, the monitored parameter may reach the limiting safety system setting at point A so that the safety system is actuated. This corrective action only becomes effective at point B because of the inherent delays of the safety system instrumentation and equipment to respond.

I.1.6 Accident Condition,(Curve No. 3)

I.1.6.1 In the event of failure in one of the safety systems or elsewhere in the plant, that is more severe than what the plant was designed to cope with, it is possible for the cladding temperature to exceed the value of the safety limit and hence significant quantities of radioactive material may be released.

I.1.6.2 This situation is an accident condition, and additional safety systems may be actuated by other parameters, whereby an engineered safety feature is brought into operation to mitigate the consequence.

APPENDIX - II

TYPICAL LIST OF DOCUMENTS TO BE MAINTAINED

II.1 Typical source documents which may be used for reviews in respect of compliance of OLCs include the following:

(a) operational recorder chart covering unit power;

(b) records of the surveillance programme including safety system testing, repair and modification;

(c) records of fuel inventory (fresh and irradiated), fuel transfers, fuel burn-up histories and core verification;

(d) records of gaseous and liquid radioactive material released to the environs and solid and liquid radioactive wastes accumulated on site;

(e) records of pressure and temperature cycles for the primary heat transport system components;

(f) records of reviews and modifications made to operating instructions and procedures or plant equipment related to operational limits and conditions or to modifications of the operational limits and conditions;

(g) records of audits;

(h) reports of human errors, or component failures in the safety systems, affecting compliance with the operational limits and conditions;

(i) special or temporary operating instructions for deviations from normal operation, abnormal occurrences, experimental requirements, etc;

(j) procedures covering the production and authorisation of operating instructions including special and temporary instructions;

(k) record of jumpering control logics, incapacitating valves or the equipment and subsequent normalisation of the same affected logic/ equipment;

(l) records of special In-service Inspections or maintenance performed on the main systems; and

(m) record of heavy water inventory, losses, collection, etc.

II.2 All the station documents shall be clearly identified and easily available at designated places at site. The station documents include the following:

(a) station logs;

(b) chronological logs;

(c) field logs;

(d) filled safety system test proforma;

(e) control room panel readings proforma;

(f) safety related unusual occurrence reports

(g) outage reports;

(h) jumper book;

(i) technical specification violation reports;

(j) twenty-day safety-related unusual occurrence reports;

(k) field inspection reports;

(l) monthly reports;

(m) weekly reports;

(n) annual reports;

(o) In-service Inspection/major maintenance reports;

(p) annual shutdown/long shutdown reports;

(q) special reports;

(r) station operation review committee meeting minutes; and

(s) quarterly health physics reports.

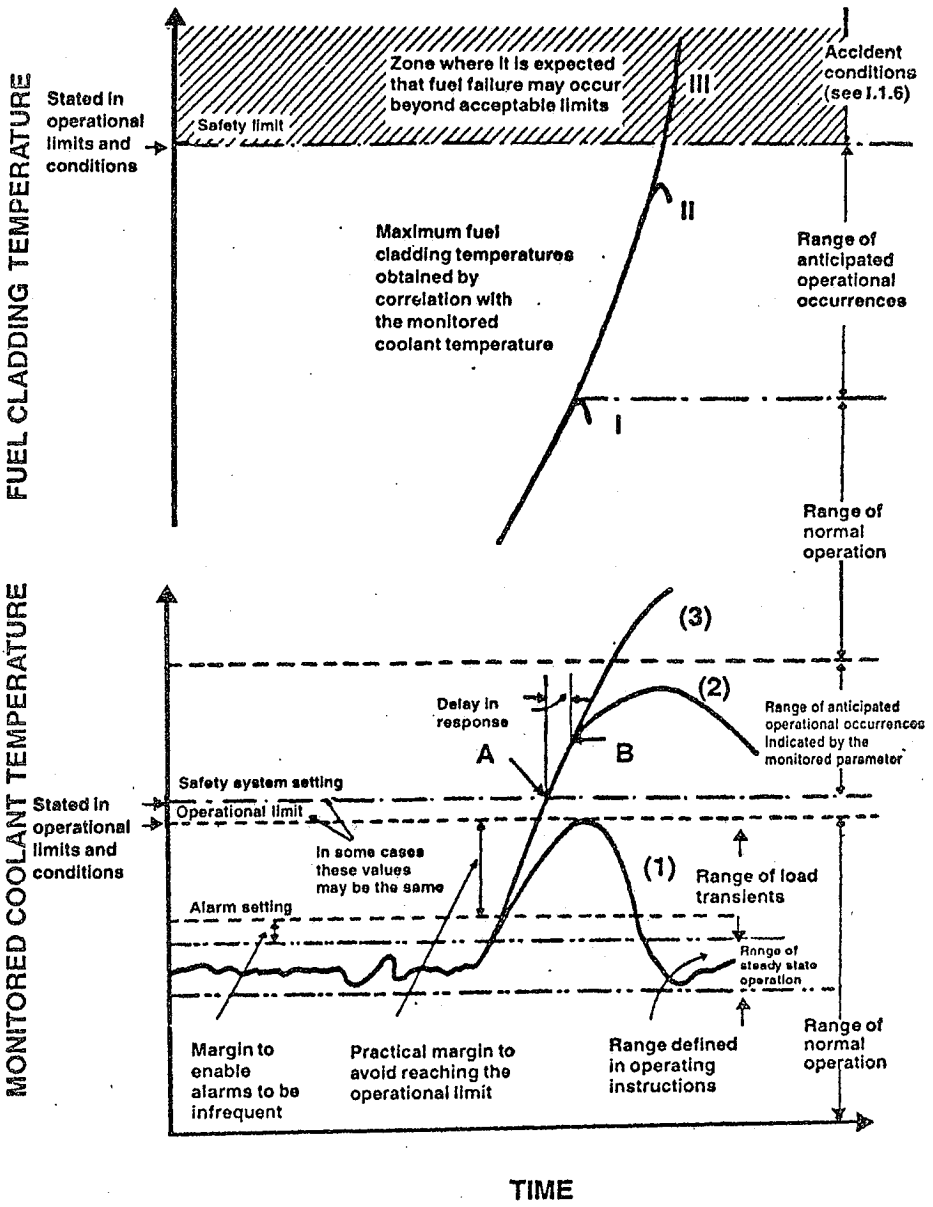

Fig. 1. Example to explain terms used in the Guide. Curves I,II and III relate to Curves 1, 2 and 3 respectively

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Dates of Meeting	:	September 28,29, 1994 November 29, 30, 1996

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Shri T.S.V.Ramanan	:	NPC
Shri Y.K. Joshi	:	RAPS/NPC
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PROVISIONAL LIST OF SAFETY GUIDES ON OPERATION OF NUCLEAR POWER PLANTS

Safety Series Nos.	Provisional Title
AERB/SG/O-1	Staffing, Recruitment, Training and Authorisation of Operating Personnel of NPPs
AERB/SG/O-2	In-Service Inspection of NPPs
AERB/SG/O-3	Operational Limits and Conditions for NPPs
AERB/SG/O-4	Commissioning Procedures for Pressurised Heavy Water Reactor Based NPPs
AERB/SG/O-5	Radiation Protection during Operation of NPPs
AERB/SG/O-6	Preparedness of the Operating Organisation for Handling Emergencies at NPPs
AERB/SG/O-7	Maintenance of NPPs
AERB/SG/O-8	Surveillance of Items Important to Safety in NPPs
AERB/SG/O-9	Management of NPPs for Safe Operation
AERB/SG/O-10A	Core Management and Fuel Handling for Pressurised Heavy Water Reactor Based NPPs
AERB/SG/O-10B	Core Management and Fuel Handling for Boiling Water Reactor Based NPPs
AERB/SG/O-11	Operational Management of Radioactive Wastes Arising During Operating of NPPs
AERB/SG/O-12	Renewal of Authorisation for Operation of NPPs
AERB/SG/0-13	Operational Experience Feedback

NOTES