MANUAL NO: AERB/NPP/SM/CSE-2

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GOVERNMENT OF INDIA

**AERB SAFETY MANUAL**

# IN-SERVICE INSPECTION OF CIVIL ENGINEERING STRUCTURES IMPORTANT TO SAFETY OF NUCLEAR POWER PLANTS

**ATOMIC ENERGY REGULATORY BOARD**

AERB SAFETY MANUAL NO. AERB/NPP/SM/CSE-2

**Atomic Energy Regulatory Board**
**Mumbai 400 094**
**India**

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# FOREWORD

Activities concerning establishment and utilization of nuclear facilities and use of radioactive sources are to be carried out in India in accordance with the provisions of the Atomic Energy Act, 1962. In pursuance of the objective to ensure safety of members of the public and occupational workers, as well as protection of environment, the Atomic Energy Regulatory Board has been entrusted with the responsibility of laying down safety standards and framing rules and regulations for such activities. The Board has, therefore, undertaken a programme of developing safety standards, codes of practice and related guides and manuals for the purpose. These documents cover aspects such as siting, design, construction, operation, quality assurance, decommissioning and regulation of nuclear and radiation facilities.

Codes of practice and safety standards are formulated on the basis of internationally accepted safety criteria for design, construction and operation of specific equipment, systems, structures and components of nuclear and radiation facilities. Safety codes establish the objectives and set minimum requirements that shall be fulfilled to provide adequate assurance for safety. Safety guides elaborate various requirements and furnish approaches for their implementation. Safety manuals deal with specific topics and contain detailed scientific and technical information on the subject. These documents are prepared by experts in the relevant fields and are extensively reviewed by advisory committees of the Board before being published. The documents are revised when necessary, in the light of the experience and feedback from users as well as new developments in the field.

Civil engineering structures form an important part of nuclear installations. This safety manual is written to specify the objectives and minimum requirements for the in-service inspection of civil engineering buildings/ structures. These are to be fulfilled to provide adequate assurance for safety of nuclear installations in India.

Consistent with the accepted practice, ‘shall’, ‘should’ and ‘may’ are used in the manual to distinguish between a firm requirement, a recommendation and a desirable option, respectively. Appendix included in the manual is an integral part of the document, whereas footnotes and references are included to provide information that might be helpful to the user. Approaches for implementation, different to those set out in the manual, may be acceptable, if they provide comparable assurance against undue risk to the health and safety of the occupational workers and the general public, and protection of the environment.

For aspects not covered in this manual, applicable and acceptable national and international standards, codes and guides should be followed. Non-radiological aspects such as industrial safety and environmental protection are not explicitly considered. Industrial safety is to be ensured through compliance with the applicable provisions of the Factories Act, 1948 and the Atomic Energy (Factories) Rules, 1996.

This manual has been prepared by specialists in the field drawn from Atomic Energy Regulatory Board, Nuclear Power Corporation of India Limited, Development Consultants Limited, TCE Consulting Engineers and Bureau of Indian Standards. It has been reviewed by the Advisory Committee on Nuclear Safety.

AERB wishes to thank all individuals and organisations who have prepared and reviewed the draft in its finalisation. The list of persons, who have participated in this task, along with their affiliations, is included for information.

Suhas P. Sukhatme

(Suhas P. Sukhatme)
Chairman, AERB

# DEFINITIONS

**Acceptable Limits**

Limits acceptable to the regulatory body for accident condition or potential exposure.

**Accident Conditions**

Substantial deviations[1] from operational states, which could lead to release of unacceptable quantities of radioactive materials. They are more severe than anticipated operational occurrences and include design basis accidents as well as beyond design basis accidents.

**Analysis**

A process of mathematical or other logical reasoning or deduction that leads from stated premises to the conclusion/ response/outcome/adequacy of a system or any other item of interest.

**Atomic Energy Regulatory Board (AERB)**

A national authority designated by the Government of India having the legal authority for issuing regulatory consent for various activities related to the nuclear and radiation facility and to perform safety and regulatory functions, including their enforcement for the protection of site personnel, the public and the environment against undue radiation hazards.

**Audit**

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

**Authorisation**

A type of regulatory consent issued by the regulatory body for all sources, practices and uses involving radioactive materials and radiation-generating equipment.

**Commissioning** [2]

The process during which structures, systems and components of a nuclear and radiation facility, on being constructed, are made functional and verified in accordance with design specifications and found to have met the performance criteria.

**Competent Authority**

Any official or authority appointed, approved or recognised by the Government of India for the purpose of the rules promulgated under the Atomic Energy Act,1962.

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[1] Substantial deviation may be a major fuel failure, a Loss of Coolant Accident (LOCA) etc.

[2] 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 co-exist; e.g. construction and commissioning or commissioning and operation.

**Construction** [2]

The process of manufacturing, testing and assembling the components of a nuclear or radiation facility, the erection of civil works and structures, the installation of components and equipment and the performance of associated tests.

**Decommissioning** [3]

The process by which a nuclear or radiation 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 the environment.

**Design**

The process and results of developing the concept, detailed plans, supporting calculations and specifications for a nuclear or radiation facility.

**Documentation**

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

**Examination**

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**

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 predetermined quality requirements.

**Item**

A general term covering structures, systems, components, parts or materials.

**Items Important to Safety (IIS)**

The items which comprise:

- those structures, systems, equipment and components whose malfunction or failure could lead to undue radiological consequences at Plant site or off-site;
- those structures, systems, equipment and components which prevent anticipated operational occurrences from leading to accident conditions; and
- those features which are provided to mitigate the consequences of malfunction or failure of structures, systems, equipment or components.

**Nuclear Power Plant (NPP)**

A nuclear reactor or a group of reactors together with all the associated structures, systems, equipment and components necessary for safe generation of electricity.

[3] This includes successive barriers set up against the release of radioactivity from nuclear facilities.

**Operating Organisation**

The organisation so designated by responsible organisation and authorised by regulatory body to operate the facility.

**Operation**

All activities following and prior to commissioning performed to achieve, in a safe manner, the purpose for which a nuclear/radiation facility is constructed, including maintenance.

**Operational Records**

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

**Plant Management**

Members of the site personnel who have been delegated responsibility and authority by the operating organisation for directing the operation of the plant.

**Qualified Person**

An individual who, by virtue of certification by appropriate authorities and through experience, is duly recognized as having expertise in a relevant field of specialization e.g. quality assurance, radiation protection, plant operation, fire safety or any relevant engineering or safety speciality.

**Quality**

The totality of features and characteristics of an item or service that have the ability to satisfy stated or implied needs.

**Quality Assurance**

Planned and systematic actions necessary to provide the confidence that an item or service will satisfy given requirements for quality.

**Quality Control**

Quality assurance actions, which provide a means to control and measure the characteristics of an item, process or facility in accordance with established requirements.

**Records**

Documents, which furnish objective evidence of the quality of items and activities affecting quality. They include logging of events and other measurements.

**Reliability**

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**

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

**Safety**

The achievement of proper operating conditions, prevention of accidents or mitigation of accident consequences, resulting in protection of site personnel, the public and the environment from undue radiation hazards.

**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.

**Site**

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

**Site Personnel**

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

**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.

**Structure**

The assembly of elements which supports/houses the plants, equipment and systems.

**Surveillance**[4]

All planned activities, viz. 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 approved by the regulatory body, covering the operational limits and conditions, surveillance and administrative control requirements for safe operation of the nuclear or radiation facilities. It is also called as 'operational limits and conditions'.

**Testing (QA)**

The determination or verification of the capability of an item to meet specified requirements by subjecting the item to a set of physical, chemical, environmental or operational conditions.

**Verification**

The act of reviewing, inspecting, testing, checking, auditing, or otherwise determining and documenting whether items, processes, services or documents conform to specified requirements.

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[4] 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 During the operating life of a nuclear power plant (NPP), the civil engineering structures might be exposed to environmental conditions whose individual and combined effects may have influence on safe functioning of the plant. The important factors are stress, temperature, erosion, corrosion, radiation effect, vibration and fretting, all of them affect structures severely depending on duration after construction/erection. In coastal sites, rate of corrosion on outdoor structures is high, particularly on structures made of concrete, steel, masonry and other embedded parts. Changes of material properties due to aging, embrittlement, fatigue and also formation and/or growth of algae, barnacle, etc., may cause defects in the structure. The defects may be imperfections, discontinuity, irregularity or fault in the structure such as crack, crevice, spalling, delamination, cavity, porosity, etc.

In view of the above, it is necessary to inspect the civil engineering structures periodically to assess whether they are acceptable for continued safe operation of the plant or any remedial measures are necessary.

1.1.2 It is necessary to review the existing buildings[5]/structures important to safety of nuclear power plants with the purpose of determining the physical condition and functionality of the structures. This may include a review of previously accomplished repairs[6], maintenance, as well as the condition surveys, testing, structural analysis and consequential repair.

The inspection programme, in which the performance and condition of plant structures are periodically studied and monitored, may be conducted to ensure that the structures continue to serve their intended function. Formulation and implementation of an inspection procedure for civil engineering structures in NPP, nuclear facilities and associated systems can serve many purposes including those listed below:

(a) provide documented evidence of continued satisfactory performance and function through periodic inspection;

(b) identify and arrest/mitigate age-related degradation at early stages;

(c) provide guidance for the development of an effective maintenance programme;

(d) support the application for an extended operating licence;

(e) provide baseline condition data for comparison following a seismic event, short-term environmental load, a design basis accident (DBA) or beyond design basis accident (BDBA);

(f) provide configuration and material property information for structural re-analysis, physical modification, or similar activity.

Such inspections performed during the operating life of a plant are described in this safety manual on in-service inspection. Principal recommendations, methods, frequency and administrative measures are also given in this manual.

1.1.3 Principal objective of in-service inspection is to evaluate the status of the structure with respect to continued safe performance following the criteria stated in the document. The criteria given in the maintenance manual are pertinent only with respect to the maintenance aspect. Inspection for maintenance is a regular feature and is carried out at higher frequency while in-service inspection, being more thorough, may be carried out at a lower frequency and after occurrence of any abnormal event. If scheduled maintenance inspection coincides with that of in-service inspection, then both can be performed concurrently.

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[5] Buildings are generally enclosed structures cladded with structural/nonstructural elements to provide appropriate operations environment, housing and support for personnel, structures, systems and components.

[6] Repairs: The process of restoring a non-conforming item to a condition such that the capability of this item to function reliably and safely is unimpaired, even though that item still may not conform to the prior specification.

1.1.4 In-service inspection requires approprite provisions in the design of the plant for accessibility to the structural components to be examined and for keeping radiation exposures of examining personnel as low as reasonably achievable (ALARA) and within the permissible limits.

1.1.5 The extent and stringency of in-service inspection requirements shall be appropriately related to the importance to safety of the structures to be inspected and tested. The acceptance standards for inspections, tests and corrective actions, such as repair of structures, if ascertained to be unsatisfactory, should be chosen accordingly. Safety classes assigned to the structures in the design of the plant may also be taken into consideration for in-service inspection classification. The in-service inspection programme forms part of the measures to be taken by the operating organisation for ensuring safe operation of the nuclear power plant.

## 1.2 Scope

1.2.1 The safety manual outlines provisions for the preparation of in-service inspection programme for civil engineering structures mentioned in subsection 3.1.1.

1.2.2 In recommending the extent of in-service inspection of the civil engineering structures, general guidelines are given on the methods, techniques, acceptance criteria and the minimum frequency of inspections and tests.

1.2.3 The in-service inspection programme includes those inspections and tests which are to be performed during the operating life of the nuclear power plant. Approach for in-service inspection of civil engineering structures of decommissioned plant should be addressed at the time of development of decommissioning procedure for the plant.

1.2.4 In addition to the above, this manual recommends methods for preparing necessary documentation, procedures and records by the operating organisation as well as requirements for witnessing or verifying results and qualifications of the inspecting personnel. Details on leakage rate testing of containment structures and leakage testing of other fluid retaining structures, though part of in-service inspection, are covered in safety guide on Proof and Leakage Rate Testing of Reactor Containments (AERB/SG/O-15) and AERB Safety Standard on Civil Engineering Structures Important to Safety of Nuclear Facilities (AERB/SS/CSE) respectively.

1.2.5 Whenever life extension is to be considered, a specific programme will be made by the operating organisation and will be got approved by AERB. This aspect is not an item of in-service inspection and hence not covered in detail in this manual. During the in-service inspection, records will be maintained to show the ageing effects on materials used in civil engineering construction, such as concrete, steel, water stops, interfaces of embedded parts, plastic and metallic liners, embedded instrumentation, polyurethane, etc. In particular, concrete exposed to environment should be checked in detail during in-service inspection (of course, this will be attended to during maintenance work) for deterioration due to sulphate attacks, chloride ingress and carbonisation and documentation will be prepared and kept on record. This will be useful for considering extended life of the station beyond its normal service life. The areas subjected to high flux zones may not be approachable but periodically, say every eight years, computations can be made for damage due to gamma radiation, neutron radiation and heat effects. The technology for inspection of civil works as it changes, new non-destructive tests methods (NDTs) and instrumentation will be available, which should be used for assessing the condition of various civil engineering materials.

1.2.6 The guidelines for in-service inspection, included in this manual, are based on available data and experience.

## 2. DESIGN CONSIDERATIONS

2.1 The layout and design of buildings and other civil engineering structures; plant layout; and arrangement of systems, components and equipment should be reviewed during the design stage to ensure that all the required inspections and tests can be satisfactorily performed.

For this purpose the following considerations should be included:

(a) provision of adequate clearances to permit access to personnel and equipment and to facilitate the methods and techniques to be used to conduct the inspections. Provisions necessary for such an access shall be permanent so that no extra efforts are required later;

(b) adoption of suitable geometry, keeping in view the limitations of the inspection techniques;

(c) need to minimise radiation exposure to personnel to a value as low as reasonably achievable (ALARA);

(d) provision for erection of all types of working platforms, installation and support of test equipment or handling machinery, wherever required, to facilitate inspection/testing;

(e) provision for conducting inspections by different methods in case indications are revealed, the requirement of such alternative inspections;

(f) performance of operations associated with repair of structures in the event that structural defects or flaw indications are revealed, the requirement of such repairs; and

(g) provision for adequate illumination, ventilation and proper safety arrangements, such as handrail, cage ladders, etc.

2.2 All design information related to in-service inspection shall be available to the operating organisation well ahead of the commissioning programme, so that it can review the in-service inspection programme before the commencement of operation.

2.3 The designer shall specifically recommend the scope of such an inspection, so that the operating organisation can organise and conduct such inspection. In addition, the designer shall also furnish details of instrumentation, wherever provided in the structure.

2.4 A confirmation by the appropriate construction wing of the Responsible Organisation (RO) is necessary to ensure that such measures have been built-in, so that such facilities are available for in-service inspection.

# 3. IN-SERVICE INSPECTION (ISI)

## 3.1 In-service Inspection Procedure

The civil engineering structures subjected to in-service inspection shall be inspected by visual method as a general rule and by surface and volumetric methods, wherever necessary on the basis of findings of visual method. In addition, in-service testing to ascertain possible leakage shall check the integrity of the pressure-retaining structures.

3.1.1 In establishing the extent of the in-service inspection programme, consideration shall be given to the following structures in accordance with their importance to safety:

(a) containment structures including reactor building (RB) raft,

(b) reactor building internal structures,

(c) spent fuel storage (SFS) and spent fuel transfer structures,

(d) control building,

(e) induced draught cooling tower structures,

(f) reactor auxiliary building (RAB) and station auxiliary building (SAB),

(g) service building (SB),

(h) stack,

(i) waste management building structures,

(j) pump house structures,

(k) turbine building/turbo generator supporting structures, and

(l) other structures important to safety like diesel generator building, diesel storage and trenches and tunnels etc.

## 3.2 Pre-service Inspection

3.2.1 It is emphasised that for successful implementation of this programme, the inspections, tests and evaluation shall be performed before commencement of the operation. This will provide the baseline data with which inspection and test results of the in-service inspection programme may be compared. The possible development of flaws and acceptability of structural elements may be assessed on the basis of this comparison.

3.2.2 For plants, which are already in operation, the baseline data should be established from earlier inspection reports, tests conducted and documents, such as drawings and design manuals.

3.2.3 Pre-service inspection shall be performed before the commencement of operation to provide data on initial conditions supplementing manufacturing and construction data as a basis for comparison with subsequent inspections. This inspection shall therefore, be similar in methods, techniques and use of equipment as those which are planned to be used later on during ISI, as far as practicable.

3.2.4 The pre-service inspection shall be extended to cover all structures or structural parts, which are subject to in-service inspection.

3.2.5 When any structural part is repaired or replaced, a pre-service inspection shall be performed on that part prior to its commissioning.

3.2.6 Shop and field inspections performed during construction may form part of the pre-service inspections where inspections, after final installation and testing are, not practicable, provided that:

(a) such inspections are conducted under similar conditions and with equipment and techniques equivalent to those, that are planned to be employed during subsequent in-service inspections;

(b) examinations are conducted before a hydrostatic pressure test, followed by a confirmatory inspection after the test, on a sample of inspection areas to demonstrate that no significant change has occurred;

(c) in the case of containment or fluid-retaining structures, the inspections are performed after the hydrostatic or pneumatic pressure test, as the case may be; and

(d) the shop and field inspection records are documented and identified in a form consistent with the recommendations of the manual.

**3.3 Schedules**

3.3.1 The station authorities of the operating organisation should define the frequency at which ISI is conducted within the inspection procedure. Frequency should also take into consideration the aggressiveness of environmental conditions. The established frequency should also provide assurance that any age-related degradation is detected at an early stage and appropriate mitigative actions can be implemented. In general, it is recommended that all safety-related structures be visually inspected, where access is feasible, during the plant operation. The frequency of inspection may vary from plant to plant. Typical inspection frequency for some structures is given in Table 3.1. Requisite equipment for inspection shall be available at operating plant sites.

3.3.2 The frequencies are subject to revision based on specific plant environments or observed degradations, which dictate that an increased rate of inspection may be prudent.

3.3.3 The integrity of any prestressing system employed at a plant, including anchorage hardware, effectiveness of corrosion inhibiting material (grease or grout), and level of prestress, where feasible, should be assessed at four-year interval, or as required under the licensing requirements.

3.3.4 For structures located below grade or otherwise inaccessible, tests for quantifying the aggressiveness of the environment to which the structure is exposed may also be performed. For such structures, it would be essential to examine soil and groundwater chemistry and evaluate their propensity to cause concrete degradation or reinforcing steel corrosion. If these environmental tests suggest that an aggressive environment exists, then further evaluation at an increased frequency may be required. If structural integrity/stability is endangered due to changes in sub soil strata, then causes of such changes should be identified and suitable mitigative action should be taken immediately. Changes in subsoil strata will be apparent from excessive settlement, tilting, erosion and changes in relative density.

## TABLE 3.1 : FREQUENCY OF INSPECTION OF STRUCTURES

| Sl. No. | Structures | Frequency of inspection |
|---|---|---|
| 1 | Reactor building containment | Once in four years |
| 2 | Internal of reactor building | Once in eight years |
| 3 | Spent fuel storage bay, reactor auxiliary building | Once in four years |
| 4 | Spent fuel transfer duct<br><br>Stack | Once in four years during long shutdown for areas showing specific need, such as leakage from transfer mechanism<br><br>Once in four years by remote optical methods and testing of in-situ concrete by taking specimens, if signs of deterioration appear |
| 5 | Embedded parts (EPs) and penetrations<br><br>(a) Inland site<br>(b) Coastal site | Checking important EPs and random checks (exposed to external environment) of other EPs showing signs of deterioration<br><br>Once in two years<br>Once every year |
| 6 | Steel structures exposed to external<br><br>(a) Inland site<br>(b) Coastal site | Sample checks on steel members showing environment signs of deterioration<br><br>Once in two years<br>Once every year |
| 7 | All remaining structures and buildings | Once in eight years |

Note: In general, inspections are carried out by visual methods at the specified frequencies.

### 3.4 Acceptance Standards

3.4.1 The following findings from visual inspection or condition survey are considered acceptable and which do not require any further evaluation. These are termed as the first-tier criteria.

3.4.1.1 General Concrete Surfaces

The concrete surfaces, which are exposed for inspection and meet the following surface condition attributes, are generally acceptable without further evaluation:

(a) absence of leaching and chemical attack,

(b) absence of abrasion, erosion and cavitation,

(c) absence of poorly consolidated concrete areas,

(d) popouts and voids less than 20 mm in diameter or equivalent surface area,

(e) scaling less than 5 mm in depth,

(f) spalling less than 10 mm in depth and 100 mm in any dimension,

(g) absence of any signs of corrosion in reinforcing steel system or anchorage components,

(h) passive cracks, less than 0.4 mm in maximum width, measured on the surface of structural concrete (passive cracks are defined as those showing no sign of recent growth and absence of other degradation mechanisms at the crack), and

(i) absence of deflections, settlements, or other physical movements in excess of design serviceability criteria.

3.4.1.2 Concrete Surfaces Lined by a Metallic or Plastic Liner

Concrete surfaces that have been protectively lined with a metallic/plastic liner system are acceptable under the following criteria:

(a) Without Leak Detection System

(i) Absence of bulges or depressions in liner plate (those appear age-related or being created during construction)

(ii) Absence of any form of corrosion or other liner damage

(iii) Absence of cracking or deterioration of base and weld metal

(b) With Leak Detection System

(i) No detectable leakage observed in leak detection system

(ii) Absence of bulges or depressions in liner plate (those that appear age-related as opposed to construction phase related)

Inside surfaces of calandria vault are excluded from such normal inspection.

3.4.1.3 Areas Around Embedments in Concrete

The condition of the concrete areas around embedments is acceptable if the following criteria are met:

(a) concrete surface condition attributes as per section 3.4.1.1 are met,

(b) absence of corrosion on the exposed embedded metal surfaces and corrosion stains around the embedded metal,

(c) absence of detached embedments or loose bolts, and

(d) absence of degradation signs due to vibratory loads from piping and equipment.

3.4.1.4 Joints, Coatings, and Non-structural Components

The condition of joints, protective coatings, waterproofing membranes, and other non-structural elements is acceptable if the following criteria are met :

(a) no signs of separation, environmental degradation, or water leakages are present in joints or joint material,

(b) loss of degraded areas of coatings is limited to 4000 $mm^2$ at one location, and 10,000 $mm^2$ over the gross surface of the structure. This criteria applies to structures which do not serve as a barrier to aggressive chemical flows,

(c) absence of degradation in any waterproofing membrane protecting below-grade concrete surfaces (within the inspected area),

(d) non-structural elements are serving their desired functions satisfactorily, and

(e) discolourisation.

3.4.1.5 Prestressing Steel Systems

Exposed surfaces of components of a prestressing steel reinforcement system are acceptable if the following conditions are met:

(a) absence of grease or corrosion inhibiting wax on exposed concrete or steel surface,

(b) absence of corrosion on exposed grease cans, bearing plates, anchorages, or other components,

(c) configuration of anchorage components remains unchanged (as per structural drawings),

(d) absence of concrete degradation around anchorages (as per section 3.4.1.1 above),

(e) no signs of corroded, broken or failed prestressing elements, and

(f) no loss of prestress below acceptable levels established during the design and construction phases (percent maximum loss), as measured by lift-of testing method.

3.4.1.6 Steel Structures

(a) Steel structures are mainly subjected to failures due to corrosion, paint peel off and improper usage. The following aspects are to be identified during the inspection of steel structures:

(i) physical condition,

(ii) rate of corrosion,

(iii) cause of deterioration, and

(iv) usage for purposes other than those intended in the design.

(b) The condition of the steel structures and surfaces which are exposed for inspection and fulfill the following surface conditions are generally acceptable without further evaluation:

(i) absence of any corrosion and pitting;

(ii) absence of paint damage;

(iii) absence of any debris that may have been left on the surface, particularly on ferrous items such as screws, pop rivets, bolts, sheet metal off-cuts, etc.;

(iv) absence of sand and dirt, salt deposition, etc., which may result in corrosion in the subsequent phase;

(v) absence of moisture buildup in and around the areas considered unless it is considered in the design originally;

(vi) absence of visible damages, such as cracks due to impact of heavy loads or excessive loading, etc.;

(vii) absence of weld deterioration /separation cracks;

(viii) absence of fatigue cracks in welds or in members, particularly those subjected to cyclic loading;

(ix) all bolted connections are intact; no loosened bolted joints are observed; locknuts, if provided, do exist;

(x) absence of deflections in excess of design limits, impairing the serviceability of the structure;

(xi) absence of vibrations/resonance in excess of design limits in the structures supporting the vibratory equipment;

(xii) absence of buckling;

(xiii) condition of the handrails, treads and staircases are intact, particularly with respect to weathering of paint, rusting and breakages;

(xiv) absence of slipperiness (lack of grip) and absence of needle-like surfaces, etc.;

(xv) that the structure is used exactly for the purpose it is intended in the design and no further attachments by way of monorails, pulleys or member extensions have been added;

(xvi) if any of the conditions are not matching, then the structures are to be further investigated using suitable non-destructive testing; and

(xvii) if any corrosion protection systems other than painting have been resorted to in the original design, then the effectiveness of such systems shall be ensured to be in line with the desired level of protection; else, non-destructive testing shall be done to find out the level of damage.

(c) Some of the general conditions to be followed include:

(i) unless specified, inspection frequency for steel structures shall be decided based on the corrosion rates in the vicinity of the area of the nuclear power plant, though the preferable frequency is once in four years;

(ii) thickness measurements need to be done at a sufficient number of locations of the members, based on the member dimension. However at least five measurements are necessary for arriving at the average thickness, in case of corrosion;

(iii) the general rule is that the maximum average decrease in the thickness of the member due to corrosion over any considerable area shall never be allowed to exceed the corrosion allowance provided in the design calculations. However, if loss of material is more than 20 percent in thickness, then it shall be further examined using non-destructive methods of examination;

(iv) parts having failures and requiring repairs shall be studied. Continued usage of the parts safely till the next inspection or till the completion of the repair shall be ensured. Else, a warning for not using the same shall be recorded and communicated to all concerned; and

(v) areas, which do not meet the requirements given in (i) to (xvii) of 3.4.1.6(b) above need to be further evaluated using non-destructive tests. Capacity of members to safely carry the loads without endangering safety shall be ensured. Original member design conditions have to be utilised strictly before qualifying the members safe. Such findings need to be recorded and, if required, the consent of the design engineer is to be obtained.

3.4.2 In cases where acceptance standards are not in existence or are not relevant to the situation, acceptance standards shall be established in consultation with the Regulatory Body.

3.4.3 The criteria for qualification of the inspection personnel are to be as per the provisions of the section 7.3.

### 3.5 Supplementary Inspections

3.5.1 The findings during visual inspection shall be reviewed in order to judge whether the inspection is adequate or needs further evaluation using enhanced visual inspection (magnification, etc.), testing or other analytical technique or repair. These are termed as second-tier criteria for inspection.

When a defect, not meeting the acceptance standards outlined as per sections 3.4.1.1 to 3.4.1.6 above, is found, supplementary inspections may be performed to examine the specific area.

When the criteria are exceeded or the observed conditions need further evaluation, then criteria in sections 3.5.1.1 to 3.5.1.5 shall be considered.

3.5.1.1 During the additional inspections the observed condition of concrete surfaces of the structure shall be compared to the criteria detailed below to determine if the structure is acceptable or requires further inspection or repair.

(a) appearance of leaching or chemical attack,

(b) areas of abrasion, erosion and cavitation degradation,

(c) poorly consolidated concrete areas, which may exceed the cover, concrete thickness in depth,

(d) popouts and voids less than 50 mm in diameter or equivalent surface area,

(e) scaling less than 30 mm in depth,

(f) spalling less than 20 mm in depth and 200 mm in any dimension,

(g) corrosion staining of an undefined source on concrete surface,

(h) passive cracks less than 1 mm in maximum width, and

(i) passive settlements or deflections within the original design limits.

3.5.1.2 Concrete Surfaces Lined by a Metallic or Plastic Liner

(a) Without Leak Detection System

Presence of any condition listed in section 3.4.1.2 above shall be further evaluated to determine acceptability.

(b) With Leak Detection System

Presence of leakage in excess of amounts and flow rates in the original design or technical specification will necessitate root-cause investigation and assessment of the need for follow-up action to bring to the notice of the Regulatory Body. Leakage within the prescribed limits may be acceptable if the source is known and not found to be perennial.

3.5.1.3 Areas Around Embedments in Concrete

Presence of any condition listed in section 3.4.1.3 above shall be further evaluated to determine acceptability.

3.5.1.4 Joints, Coatings and Non-structural Components

Presence of any condition exceeding the limits and descriptions of section 3.4.1.4 shall be further evaluated to determine acceptability. Any observation of widespread adhesion/cohesion problems, environmental attack, or poor performance indicators shall be considered unacceptable.

3.5.1.5 Prestressing Steel Systems

Presence of corrosion or other conditions exceeding the limits and descriptions of section 3.4.1.5 shall be further evaluated to determine acceptability.

## 3.6 Enhanced/Augmented Inspections

3.6.1 Observed concrete surface conditions which exceed the acceptance limits provided in section 3.5 or conditions found to be detrimental to the structural or functional integrity as a result of the review of section 3.5, shall be considered non-conforming and require further inspections by using appropriate techniques to facilitate further technical evaluation.

3.6.2 Where inspection of an area results in the evaluation of flaw indications in accordance with the provisions of section 4 and qualifies the structure/element as acceptable for continued operation, that structure/element containing such flaws shall be re-examined during each of the next three inspection periods, as an extra requirement above the original schedule.

3.6.3 If the re-inspections indicate that the flaw remains essentially unchanged, the inspection schedule may revert to the original.

## 3.7 Inspection of Inner Containment

3.7.1 Concrete surfaces, which are exposed for inspection and meet the following surface condition attributes, are generally acceptable without further evaluation:

(a) External surfaces as per section 3.4.1.1

(b) Inner surfaces

   (i) absence of leaching and chemical attack,

   (ii) absence of abrasion, erosion and cavitation,

   (iii) absence of poorly consolidated concrete areas,

   (iv) absence of popouts and voids,

   (v) absence of scaling,

   (vi) absence of spalling,

   (vii) absence of any signs of corrosion in reinforcing steel system or anchorage components,

   (viii) passive cracks on the inner surface less than 0.1 mm in maximum width, and

   (ix) absence of deflections, settlements or other physical movements in excess of design serviceability criteria.

3.7.2 Concrete Surfaces Lined by a Metallic or Plastic Liner

Concrete surfaces that have been protectively lined with a metallic or plastic liner system, are acceptable under the following criteria:

(a) absence of bulges or depressions in liner plate (those that appear age-related as opposed to being created during construction),

(b) absence of any form of corrosion or any other liner damage, and

(c) absence of cracking or deterioration of base and weld metal.

3.7.3 Areas Around Embedments in Concrete

The condition of the concrete areas around embedments is acceptable if the following criteria are met:

(a) concrete surface condition attributes as per above,

(b) absence of corrosion of the exposed embedded metal surfaces and corrosion stains around the embedded metal,

(c) absence of detached embedments or loose bolts, and

(d) absence of indications of degradation due to vibratory loads from piping and equipment.

# 4. EVALUATION OF INSPECTION RESULTS

4.1 The operating organisation shall ensure that the results of every inspection are evaluated to determine compliance with acceptance standards.

4.2 Any inspection giving indications of distress/deterioration exceeding the acceptance criteria may be supplemented by other non-destructive inspection methods and techniques, to establish the character of the defect (i.e. size, shape and orientation) and thus determine the suitability of the structure for further operation. It should be ensured, while choosing supplementary techniques and methods, that the conditions affecting the structure are thoroughly investigated.

4.3 If analytical methods are employed, the stresses in the area of the distress/deterioration shall be analysed for all conditions of operation, including postulated accident conditions and actual as well as predicted normal operating conditions. The worst stress case shall then be selected. The values of the material properties used in the analysis should be those actually measured, but if such data does not exist, it should be assumed that the properties conform to the most conservatively accepted values for the particular type and grade of the material showing the defect. Wherever the properties of the material may be altered by its environment, such as by irradiation, samples should be used to establish the actual change in material properties and where samples are not in existence, it may be assumed that the changes due to such environments follow the authentic/reliable data published. All aspects of the problem should be taken into consideration so that assumptions always involve the worst case in the analysis. The calculation methods should be in accordance with the accepted standards. Help from the designer shall be taken for any such analytical evaluation. If no such help was sought and the work was completed, then the results of such analytical evaluation shall be got approved from the designer.

4.4 Analytical methods involve the use of additional or supplementary calculations or analyses to evaluate the structural behaviour and resistance of the structure, use of advanced computer-enhanced analysis, finite element analysis, and structural reanalysis using design provision adopted. It may also be necessary to recalculate the capacity of the structure or its sub-element in question as the original calculations may not be available or the design may be governed by calculations for a physically similar but different structure. In general, some form of analysis will be required, if any potentially significant degradation is found during the inspection/testing phase. An independent analytical exercise to determine the design basis resistance requirement of the degraded structure considering the in-situ properties of material is useful for the purpose of comparision with original calculation. This may reveal over-conservatism in design, or confirm the need to implement a rehabilitation programme.

It may be necessary to evaluate the protection provided by the existing cover of concrete to the reinforcing steel system from the environment, fire effects, etc.

Probabilistic methods such as a probabilistic risk assessment (PRA), individual plant examination of external events (IPEEE), and time-dependent reliability analyses may also be useful during an evaluation. In addition, such methods may have already been employed at the specific plant; the conclusions from any of these studies are useful for prioritising structures and determining the degree of degradation that may be accepted while meeting functional requirements. Bayesian statistics may also be used to improve the determination of material properties from reduced quantity of test data.

Analytical methods may also be used in combination with limited destructive testing to examine structural capacity of the existing structure on the basis of in-situ concrete strength. In-situ concrete strength may be higher than considered in the original design calculations, even in the presence of degradation.

Loads reconciliation is an analytical method which involves the review of as-built dead and live loading applied to the structure in question to determine actual exposure, as well as for re-assessing the use of the structure in the plant's operation. The results of this review are compared to the original design loading combinations to identify the presence of margins. The margin shall be confirmed to ensure that appropriate safety factors are maintained to support the structural function. The balance of the margin may be used to justify a limited amount of discontinuities or degradation in the structure.

4.5 When the evaluation result is declared by the designer as per sections 4.3 and 4.4 as unacceptable for continued operation; then the structure shall be repaired/strengthened or rebuilt. As a result of inspection of distress/deterioration, the requisite repairs and replacement should be carried out as per the maintenance manual. In special cases, procedures for repairs/rehabilitation shall be got approved by competent authority and the procedure implemented. Abnormal cases shall be reported to the Regulatory Body.

# 5. REPAIR AND REPLACEMENT

5.1 Structures after repair should be restored to their desired strength, durability and serviceability. During selection and implementation of repair procedure, the following shall also be considered.

(a) environmental conditions at structure (e.g. radiation, temperature, corrosion condition, etc.),

(b) type and degree of degradation (e.g. monolithic, aesthetic),

(c) mitigation of degradation effects in the repair process,

(d) existing material properties (for repair material compatibility),

(e) desired service life of structure and proposed repair,

(f) availability of repair material qualification data,

(g) economics,

(h) restoration of structural capacity, and

(i) restoration of service characteristics.

5.2 The structures should be repaired in accordance with the codes and standards that were applied at the time when the structure was constructed and in accordance with the quality assurance programme in effect at the time of repair.

5.3 Replacement should meet the provisions and requirements of the codes, standards and other special instructions that were applied to the construction of the structure or the part of the structure to be replaced. Alternatively, replacements may meet the requirements of new editions of codes or new codes and standards, or portions thereof, provided that:

(a) the requirements affecting the design, construction/fabrication and inspection are reviewed and it is determined that the original safety requirements are not reduced;

(b) mechanical interfaces, fits and tolerances affecting performance are not changed by the new editions or the new codes or standards; and

(c) the materials are compatible and suitable for the installation and operating requirements of the system.

5.4 Structures that are repaired or replaced for any reason shall be re-examined in accordance with the provisions of the manual. Before pressure-retaining structures are restored to service, they shall be tested in accordance with the following for acceptance:

(a) water-retaining structure as per AERB/SS/CSE-1 (Appendix-G), and

(b) containment structures as per AERB/SS/CSE-3

5.5 When the structures require modification, alteration or additions, the provisions in this manual for repair and replacement shall be used.

# 6. EQUIPMENT, METHODS AND TECHNIQUES

## 6.1 Equipment

6.1.1 All equipment used for inspections and tests shall be of quality, range and accuracy in accordance with the standards recognised by the competent authority.

6.1.2 All equipment together with their accessories shall be calibrated before being used. The equipment shall be properly identified with calibration records and the validity of calibration shall be verified regularly, by the operating organisation, in accordance with the quality assurance programme.

## 6.2 Methods and Techniques

6.2.1 General

Methods and techniques for conducting ISI shall be in accordance with standards recognised by the Regulatory Authority and are categorised as

(a) visual,

(b) surface, and

(c) volumetric.

6.2.2 Visual Inspection

Visual inspection is used to provide information on the general condition of the part, component or surface to be examined, including such conditions as scratches, wear, cracks, corrosion or erosion on the surface; or evidence of leakage. Optical aids, such as television cameras, binoculars and mirrors may be used.

Surface replication, as visual inspection method may be considered acceptable, provided that the surface resolution is at least equivalent to that obtainable by the visual observation.

Appropriate cleaning processes shall precede visual inspection that requires clean surfaces for valid interpretation of results.

Visual inspection, or condition survey, is a non-invasive technique, which may provide significant quantitative and qualitative data regarding structural performance and extent of degradation. Visual inspection encompasses a number of activities, including direct and indirect inspection of exposed surfaces, crack and discontinuity mapping, physical dimensioning, environmental surveying and protective coating review. This technique may be used to define the current condition of the accessible concrete structure in terms of the extent and cause of degradation, material deficiencies, performance of coatings and cover of concrete, damage from loads and stresses, and response to applied loads (as witnessed by vibration, deflection, settlement, cracking, spalling, and strain).

The scope of the visual inspection should include all exposed surfaces of the structure, joints and joint material, interfacing structures and materials (e.g. abutting soil), embedments and attached components, such as base plates and anchor bolts. These components should be directly viewed (maximum 600 mm focal distance) if possible, and photographs or video images taken of at discontinuities, defects, and significant findings. Use of binoculars, fibrescopes and other optical aids is recommended to gain better access, augment the inspection or further examine any discontinuities. Such equipment should have suitable resolution capabilities, under ambient or enhanced lighting, as good as for direct viewing. The condition of surrounding structures should also be observed in order to facilitate better assessment of the aggressiveness of the operating environment.  Visual inspection also requires the use of physical measuring equipment for dimensioning and measuring the size of degraded areas. This equipment should be in good working condition, and either properly calibrated or verified for the required accuracy. For crack investigations, a feeler gauge, optical crack comparator, mechanical movement indicator and data acquisition system should be used for quantifying the activity, width, depth, and the extent of degradation. For crack length measurement and general dimensioning purposes, a standard metal tape shall be provided with desired accuracy.

### 6.2.3 Surface Inspection

A surface inspection is undertaken to delineate or verify the presence of surface or near-surface flaws or discontinuities. It may be conducted by non-destructive methods, such as sounding, acoustic, magnetic, dye penetration and magnetic particle technique, radiography etc.

### 6.2.4 Volumetric Inspection

A volumetric inspection is undertaken for the purpose of indicating the presence, depth or size of a sub-surface defect or discontinuity, and usually involves radiographic, ultrasonic or eddy current techniques.

# 7. ADMINISTRATIVE ASPECTS

## 7.1 Responsibilities of the Operating Organisation

7.1.1 The operating organisation shall be responsible for establishing and implementing the in-service inspection covered by this manual. These responsibilities normally include:

(a) review of the plant design and arrangement of the system components to ensure that all in-service inspections and tests can be performed satisfactorily and that radiation exposures to personnel conducting inspections are maintained as low as reasonably achievable (ALARA);

(b) preparation of in-service inspection programmes and schedules for inspections;

(c) development and preparation of instructions and procedures, including diagrams or drawings identifying the structure, specifying the area which is subject to inspection, and describing the method of locating that area on the structure;

(d) audit of the in-service inspection programme;

(e) the assurance that inspections are performed by qualified personnel;

(f) conducting ISI in accordance with the inspection programme and the written procedures;

(g) analysis and evaluation of the results of each inspection and test;

(h) preparation and implementation of detailed programmes for repair, replacement or modification;

(i) preparation of records of all inspections and test results that provide a basis for evaluation and facilitate comparison with the results of subsequent inspections;

(j) keeping and retention of adequate records of inspections, tests analysis and evaluations performed, such as radiographs, diagrams, drawings, reports, data and personnel qualifications; and

(k) submission of any of the preceding information, which the Regulatory Body may require.

7.1.2 The operating organisation shall ensure that the in-service inspection programme both as a whole and in detail is reviewed in the light of experience and of changed local plant conditions and revised as necessary. The in-service inspection programme should be in compliance with the provisions in section 3.4.

## 7.2 ISI Documentation

7.2.1 Documents shall be prepared to cover all the inspections and tests to be carried out during the operating life of each nuclear power unit. They shall include such information as:

(a) the selection of structures to be examined,

(b) the determination of the type of inspection,

(c) the selection, location and extent of areas to be examined and inspection frequency,

(d) the methods and techniques to be used for inspections, and

(e) the assessment of radiation doses expected to be received during the inspections or tests.

7.2.2 Where it is necessary to demonstrate compliance with the requirements of the Regulatory Body, documents containing the following shall be prepared:

(a) preliminary in-service inspection programme,

(b) final in-service inspection programme, and

(c) detailed inspection and test procedures.

7.2.3 The preliminary in-service inspection programme shall demonstrate that the design of the nuclear power plant makes adequate provision for in-service inspections to be carried out. This programme should be prepared by the operating organisation in consultation with the concerned project authorities (i.e. designers and construction groups) before the final design is implemented.

7.2.4 The final in-service inspection programme shall specify in detail the pre-service inspections to be completed before the commencement of operation and the in-service inspections and tests to be performed during the operating life of the plant unit. It shall also state how and when these inspections and tests are to be performed.

7.2.5 Drawings, diagrams or sketches should be used to show the location and arrangement of structures/ structural elements and to demonstrate the feasibility of the proposed inspections.

7.2.6 The detailed inspection procedures shall be clearly identified in the in-service inspection programme and should include the following:

(a) scope of the inspection,

(b) applicable codes and standards,

(c) supporting documents,

(d) requirements relating to qualifications of inspectors,

(e) methods and equipment used,

(f) preparation of structures to be examined,

(g) requirements for calibration and re-calibration,

(h) examination procedure,

(i) indication of minimum recording level, if appropriate, and

(j) data to be recorded.

7.2.7 Special attention shall be given to recording the results of the inspection and test in a form that corroborates the completion of inspection and test in a proper manner. As an example, any special forms, which are to be incorporated in the final record, should be included as an integral part of the detailed inspection and test procedures.

7.2.8 The detailed inspection and test procedures shall be prepared, reviewed and approved before the inspections and tests are carried out to allow sufficient time for the personnel to be trained and equipment to be set up and tested.

7.2.9 Revisions and reviews of the in-service inspection programme and procedures shall be documented.

### 7.3 Inspection Personnel

7.3.1 Inspection personnel shall be adequately qualified, particularly to carry out their responsibilities on the basis of their experience with the same inspection methods as proposed to be used in the ISI programme, and employing similar materials and plant configurations.

7.3.2 Evidence shall be provided that personnel qualified as stated in section 7.3.1 have carried out the inspections. Satisfactory methods by which this could be done are :

(a) verifying the qualifications of the inspection personnel and including the relevant information in the reports of the inspections, or

(b) arranging for the issuance of qualification certificates recognised by the competent authority, or

(c) employing an organisation that is recognised by the competent authority as being qualified to perform required inspections.

### 7.4 Verification

7.4.1 Arrangements shall be made for independent verification to check that the inspections and tests comply with the requirements. Personnel deputed by the operating organisation shall carry out these verifications.

7.4.2 The final outcome of in-service inspection shall be confirmed by the operating organisation as satisfactory for continued operation and submitted to the Regulatory Body as required.

# 8. RECORDS

8.1 The records necessary for proper implementation of in-service inspection programme shall be readily available to the operating organisation and clearly identifiable (e.g. date, name of plant and operating organisation) and should include :

(a) specifications and as-built drawings,

(b) information on material used,

(c) pre-service inspection data and reports,

(d) in-service inspection programme and detailed inspection and test procedures,

(e) examination and test reports and charts,

(f) calibration records,

(g) acceptance criteria, and

(h) evaluations.

The AERB safety guide No. AERB/SG/QA-5 on Quality Assurance during Commissioning and Operation of Nuclear Power Plants, provides recommendations applicable to such records.

8.2 Item (a) of section 8.1, includes structural drawings, material specifications, records of the construction, fabrication and erection specifications and drawings and records of acceptance of deviations from specifications.

8.3 The records for each inspection shall contain the following:

(a) all pertinent information such as structure identification, location and size of inspection area, inspection technique, type of inspection equipment, type of sensor, calibration equipment, sensitivity standards, etc. such that the in-service inspection could be repeated and similar results obtained;

(b) all ultrasonic indications more than the minimum recording level and all permanent information concerning the indications (e.g. location, magnitude, length);

(c) all recordings (e.g. radiography, photograph, magnetic tape, and chart) except that when no indication is obtained, then the recording need not be kept, provided a notation to this effect is made in the record;

(d) comparisons with previous inspection results and evaluations;

(e) evaluations and reports; and

(f) radiation doses received by inspection team and repairing personnel.

8.4 Records which are directly applicable to an individual structure should be available for the life of the plant and should include as a minimum:

(a) an appropriate file index,

(b) design basis reports,

(c) design reports,

(d) as-built drawings,

(e) reports of material properties, including the results of inspections and names of the personnel interpreting the results,

(f) information on materials, regarding their material properties and other relevant information for future reference, and

(g) a record of pre-service inspection.

8.5 After selection of a repair material, process and completion of necessary supportive documents and calculations, the concerned engineer should prepare a summary report identifying the source or root cause of degradation and reason for the evaluation. The decision making behind the repair, repair material qualification data, summary of structural calculations, prepared drawings and all documents related to evaluation should be included in the summary report. This summary report should be preserved for the life of the plant.

During the repair process it is necessary to provide quality control in the form of inspections or other reviews to verify the adequacy of the repairs.

# APPENDIX

## REPORT ON IN-SERVICE INSPECTION

| | | |
|---|---|---|
| Name and Address of the plant | : | |
| Locations of Inspection | : | |
| Inspection No. | : | |
| Names of Members of Inspection Team | : | |
| Date of Inspection | : | |

Inspection report containing scope, findings, evaluation, conclusion, repairs, reference documents, etc.

Signature of Leader of Inspection Team

Verification :

Confirmation by the Head of the Operating Organisation.

(Signature)
Head of the Operating Organisation

## REFERENCES


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7. ACI (1997), Concrete Practice Part 4-1997-Evaluation of Existing Nuclear Safety-Related Concrete Structures, American Concrete Institute Manual No. ACI 349.3R-96, American Concrete Institute, Redford Station, Detroit, USA.

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9. AERB (2004), Proof and Leakage Rate Testing of Reactor Containments, AERB Safety Guide No. AERB/NPP/SG/O-15, Atomic Energy Regulatory Board, Mumbai, India.

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| | | December 14 & 15, 1999 |
| | | September 12 & 13, 2000 |
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| AERB/SM/CSE-4 | Inspection During Construction of Civil Engineering Structures Important to Safety of Nuclear Facilities |
| AERB/SM/CSE-5 | Format of Safety Design Reports |

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