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GOVERNMENT OF INDIA

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AERB SAFETY GUIDE

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MAINTENANCE  
OF  
NUCLEAR POWER PLANTS



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ATOMIC ENERGY REGULATORY BOARD

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**AERB SAFETY GUIDE No.AERB/SG/O-7**

**MAINTENANCE  
OF  
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 in the Atomic Energy Act 1962 (33 of 1962).

Assuring high safety standards has been of prime importance since the inception of the nuclear power programme in the country. Recognising this aspect, the Government of India constituted the Atomic Energy Regulatory Board (AERB) in November 1983 vide standing order No. 4772 notified in Gazette of India dated 31.12.1983. The Board has been entrusted with the responsibility of laying 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 general public and plant personnel.

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 annexures, foot-notes and references are not to be considered integral part of the document. They are included to provide information that might be helpful to the user.

The emphasis in the codes and guides is on the 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 through compliance with the Factories Act 1948 as amended in 1987 and the Atomic Energy (Factories) Rules, 1996.

This Safety Guide provides guidance on all aspects of maintenance necessary for safety in NPPs.

This safety 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 IAEA Safety Guide on "Maintenance of NPPs" (50-SG-O7 Rev-1).

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

(P. Rama Rao)  
Chairman, AERB

# DEFINITIONS

## **Acceptable Limits**

Limits acceptable to Regulatory Body.

## **Accident Conditions<sup>1</sup>**

Substantial deviations from Operational States which are expected to be infrequent, and which could lead to release of unacceptable quantities of radioactive materials if relevant items important to safety did not function as per design intent.

## **Anticipated Operational Occurrences<sup>2</sup>**

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)**

National authority designated by Government of India having the legal authority for issuing regulatory consents for various activities related to a facility and to perform safety and regulatory functions including enforcement for the protection of the public and operating personnel against radiation.

## **Audit<sup>3</sup>**

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.

## **Authorisation**

See 'Regulatory Consent'.

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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, loss of power to main coolant pump.

3 The definitions refer to quality assurance activity as discussed in quality assurance code and guides

### **Commencement of Operation<sup>4</sup>**

The beginning activity/activities towards first approach to criticality.

### **Commissioning<sup>5</sup>**

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 Atomic Energy Regulatory Board.

### **Construction<sup>5</sup>**

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<sup>5</sup>**

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<sup>3</sup>**

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.

### **Examination<sup>3</sup>**

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<sup>3</sup>**

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.

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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.

## **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;<sup>6</sup>
- (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.

## **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 personnel from undue radiological hazards.

## **Objective Evidence**

The 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.

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



## **Operating Organisation<sup>7</sup>**

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<sup>5</sup>**

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)**

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.

## **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.

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7 Organisation structure and not individual names.

**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<sup>8</sup>**

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

**Safety**

Protection of all persons from undue hazard.

**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 radioactivity (Containment Isolation System).

**Severe Accidents**

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

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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.

**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<sup>9</sup>**

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.

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<sup>9</sup> 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 is a part of the Atomic Energy Regulatory Board's (AERB's) programme for establishing Codes of Practice and Safety Guides relating to Nuclear Power Plants (NPPs). It supplements the Code of Practice on Safety in NPP Operation (AERB/SC/O). The provisional list of Safety Guides in Operation is given at the end of this publication.
- 1.1.2** Maintenance of structures, systems and components in a NPP involves the carrying out of their servicing on a timely basis in a planned and proper manner to overcome the normal wear and tear of equipment, in order to prevent their failures or to rectify the failures as and when they occur.
- 1.1.3** Post maintenance activities also comprise functional and performance testing of plant structures, systems and components, their surveillance and in-service inspection to ensure their continuing capability to perform as per design intent.
- 1.1.4** Effective maintenance is essential to ensure that the level of reliability in the performance of all structures, systems and components important to plant safety is retained during all operational states of the reactor. It is carried out in such a manner that even during the maintenance activity, specific care is taken to see that the plant safety is not jeopardised in any way.
- 1.1.5** Modifications based on operational experience or new developments are implemented as per approved procedures mainly to achieve improvement in operational safety of the plant.

## 1.2 Objectives

- 1.2.1** The structures, systems and components are required to be maintained to have the required availability and reliability to perform safety functions as specified. To achieve this, the main objectives of this Safety Guide are as under:
- (i) To emphasise the purpose, content and rationale for frequency while establishing a maintenance programme. This will involve monitoring, testing and inspection of systems, structures and components as necessary. The servicing done on them as per the maintenance programme will ensure their performance as specified by design. Such a programme should provide for:-
    - (a) preventive maintenance: routine servicing on a planned schedule to prevent failures,
    - (b) predictive maintenance: timely replacement based on condition monitoring of components before they cause any breakdown, and
    - (c) breakdown maintenance: urgent repairs/replacement when failure occurs.

- (ii) To bring out the need for setting up written procedures and exercising of control for work authorisation, isolation of equipment in plant structures, systems and components before taking up maintenance work and similarly for testing and normalising before restoring the equipment for operation following satisfactory completion of maintenance activity. It shall be ensured that plant operating limits and conditions (OLC's) are not violated in any manner prior to, during and subsequent to the maintenance activity and in case OLCs are to be exceeded in exceptional circumstances, this is done with proper procedure and authorisation.
- (iii) To impress the necessity of using proper equipment, techniques, trained and qualified personnel, rehearsals and mock-ups for shielding and remote handling tools and decontamination practices. This will guard against the effects of radiation, and will help achieve carrying out of maintenance activities with as low as reasonably achievable (ALARA) principles as related to personnel exposure to ionising radiations.
- (iv) Documentation of all activities done under maintenance for future reference.

### **1.3 Scope**

The Safety Guide covers the following management aspects of maintenance and modification at NPPs :-

#### **1.3.1 Maintenance**

- (i) Organisational and Administrative arrangements for assignment of responsibilities for establishing maintenance facilities, training maintenance staff, written maintenance procedures and work authorisations
- (ii) Establishing maintenance programme with schedules and techniques for preventive and predictive maintenance and techniques for breakdown maintenance activities.
- (iii) Upkeep of maintenance records, equipment history sheets
- (iv) Ordering, procuring, inspection, issuing and using spare parts as per approved Stores procedures and inventory control principles;
- (v) Rehearsal/mock up facilities and special training to keep radiation exposure of personnel to minimal as per ALARA principles;
- (vi) Review and Audit programme to check performance of maintenance activities including testing, in-service inspection, repair and replacement as necessary of items important to plant safety.

#### **1.3.2 Modification:**

- (i) Processing of modification proposals and their implementation to improve plant structures, systems and components with due regard to plant safety.

## **2. MAINTENANCE PROGRAMME**

### **2.1 General**

- 2.1.1** The Operating Organisation (Op.O) is responsible for establishing a maintenance programme before commencement of operation.
- 2.1.2** The Operating Organisation (Op.O) is responsible to ensure that plant management is established before commencement of operation. Plant management is responsible to ensure that a maintenance organisation is established that includes all the administrative, technical and supervisory functions needed in mobilising on-site and off-site maintenance resources. Plant management shall remain responsible for on-site maintenance using on-site and off-site resources.
- 2.1.3** The maintenance programme shall be established sufficiently in advance prior to the commissioning stage to cope with the following:-
- (1) Plant items that are already installed, but awaiting system completion and
  - (2) Plant systems as they are put into operation. In addition to defining the responsibilities for maintenance during the operating phase, the Responsible Organisation (RO) should also define in writing the responsibility for maintaining plant items during construction and commissioning.
- 2.1.4** Operating Organisation (Op.O) should collect sufficient information on maintenance needs from designers, manufacturers and from other operating plants. It should also ensure that the programme is based on good maintenance practice. To accomplish this, the op.o should arrange for personnel with maintenance experience to interact regularly with design organization right from the design stage.

### **2.2 Maintenance schedule**

- 2.2.1** Preventive maintenance entails pre-planned routine testing, inspection, servicing and overhaul of structures, systems and components. Its purpose is to detect incipient failures and to assure the continuing capability of the plant to perform its intended functions. These pre-planned activities shall be specified in preventive maintenance schedule.
- 2.2.2** Items important to safety shall be included in the preventive maintenance schedule. Operating Organisation shall review the schedule and ensure that the applicable requirements specified by AERB in documents such as Technical Specifications have been met.
- 2.2.3** The frequency and extent of preventive maintenance of items included in the schedule shall be established taking into consideration (a) performance requirements (b) the suppliers' recommendations and (c) the relevant experience of the operating organisation. Assumptions concerning the preventive maintenance schedule shall be reviewed in the light of operating experience and failure data.



- 2.2.4** The frequency and extent of preventive maintenance may be affected by the utilisation of Condition Based Maintenance Approaches. These approaches are based on the surveillance of carefully selected parameters and a special analysis of the results. This analysis may be used to justify postponement of remedial actions till next scheduled maintenance. Such decisions shall only, however, be taken at a suitable, designated level of authority in accordance with arrangement which have been subjected to review and approval by the Regulatory Body as required.
- 2.2.5** Base line data like vibrations, bearing temperatures etc.in case of rotating machinery should be generated before the equipment are put in regular operation. These data shall be used for monitoring the health of the equipment during subsequent operation and after doing major preventive maintenance. Relevant operation and maintenance data should be maintained for the purpose of trend monitoring.

### **2.3 Design liaison**

- 2.3.1** The aim of close liaison between the operating and design organisations, mentioned in Sub-section 2.1.4 should be to ensure that the final maintenance programme is based on a clear understanding of the design philosophy and plant details, that the plant is designed to facilitate and minimise maintenance and that radiation exposure to personnel is kept as low as reasonably achievable (ALARA).
- 2.3.2** The operating organisation should arrange for reviews of the design by its staff experienced in maintenance. They should check for system design and equipment construction features. This helps in monitoring of Operational Parametric data. This enables to establish a maintenance programme with minimal radiological exposure. The review should cover the following:-
1. Access to plant items
  2. Adequacy of handling devices
  3. Space available for removal and replacement of components
  4. Area available for in situ work
  5. Interference with the operation and maintenance of other structures and systems
  6. Provision of shielding and access control, both permanent and temporary
  7. Adequacy of the maintenance and storage facilities
  8. Adequacy of active drain facilities and ventilation in areas that may be used for temporary maintenance work
  9. Adequate provision for effective isolation of electrical and mechanical devices
  10. Draining and venting facilities on systems and equipment
  11. Adequacy of stocks of spare parts
  12. Provisions for handling and storing either temporarily or permanently activated or contaminated items, tools, etc. particularly in the controlled areas
  13. Ease of maintenance, inspection and decontamination of component
  14. Adequacy of documentation

**2.3.3** The Operating Organisation's previous experience or that of other operating organisations in maintaining equipment and plant should be a factor in selecting plant items. The close liaison mentioned in 2.3.1 should be maintained throughout the life of the nuclear power plant. It is particularly necessary to ensure effective and timely assistance from the design organisation when plant fault occurs or modifications are required. The Op.O should arrange feed back of operating experience and reliability data to the design organisation.

## **2.4 Maintenance Planning**

**2.4.1** Because of the complexity of a nuclear power plant, maintenance activity has to be planned in the context of overall plant management. The maintenance group should, therefore, work in close consultation with other plant management groups.

The Planning Group of the plant shall coordinate all activities for the overall plant maintenance planning. However, the maintenance group should carry out its own work scheduling within the overall plan.

**2.4.2** The organisation for maintenance will vary depending on the type of reactor (PHWR - BWR). Planning of maintenance should take into account additional maintenance load in respect of on-load fuelling reactor (PHWR) system.

**2.4.3** Advantage should be taken of any shutdown to undertake maintenance. Appropriate maintenance schedules should therefore be readily available in the event of unplanned as well as planned shut downs.

**2.4.4** Control room personnel who are directly responsible for the safe operation of the plant, shall be informed (by means of a work permit procedure See Sub-section 4.1) of all maintenance work before it commences, any changes to the plant it entails, and when the plant systems/equipment are ready to be restored to service. Adequate co-ordination should be maintained between the maintenance and control room operating personnel during the performance of the maintenance activity.

### 3. ORGANIZATION AND RESPONSIBILITIES OF MAINTENANCE GROUP

#### 3.1 Organisation

**3.1.1** The plant management shall establish a maintenance group onsite to implement the maintenance programme. Responsibility for the implementation of the programme shall be delegated to an individual designated as Maintenance Superintendent. The Maintenance Group may be divided into Mechanical, Electrical, Control and Instrument Sections, Civil Engineering and fuel handling unit and maintenance services sections. The individual leading the section may be designated as Section Head. The structure of the maintenance group and its integration with off-site resources depends on such factors as type of plant, number of reactors on one Site, local availability of suitable manpower, mode of operation of the reactors and regulations governing the employment of labour. In all cases, plant management shall ensure that sufficient numbers of adequately qualified personnel are available to implement the maintenance programme (see AERB/SG-01 on Staffing, Recruitment, Training and Authorisation of Operating Personnel of NPPs).

#### 3.2 Responsibilities

**3.2.1** The responsibilities of the maintenance management group and supervisory staff shall be defined in writing by the plant management. Plant management shall ensure that the maintenance group works in close co-ordination with such groups as operations, health physics, quality assurance, technical services, planning, fire protection, industrial safety, stores, etc.

**3.2.2** The responsibilities of the various managerial and supervisory positions should include:

- (1) **Maintenance Superintendent:** Implementing maintenance in accordance with appropriate stipulation, the policy of the operating organisation, the quality assurance programme, and the guidelines issued by plant management; reviewing and optimising the preventive maintenance schedule, administering remedial maintenance activities including plant modification where necessary; ensuring availability of adequate maintenance procedures; administering maintenance personnel, including training and qualification; ensuring provision of tools and equipment; reviewing and approving records; reporting to plant management.
- (2) **Section Heads:** (in the area of their responsibility) Implementation of maintenance in accordance with the quality assurance programme and the instructions of the maintenance superintendent; specification and inventory control of spares; preparation of maintenance procedures and updating of the same in the light of experience, e.g. radiation exposure, work methods; provision of adequate supervision of the work, assistance in administration of maintenance personnel, planning and allocation of resources in accordance with the overall plan; reporting progress and results to the maintenance superintendent; review and approval of reports and records.

- (3) **Supervisors:** (in the area of work assigned to them) allocation of resources to the various jobs in the daily work plan; observation of progress and quality of work; assurance that procedures are followed: generation, collation and processing of records; report of work status and progress.

It shall be the responsibility of the maintenance superintendent, section heads and supervisors to take into account the need to keep exposure of personnel as low as reasonably achievable.

### **3.3 Selection and Training of Maintenance Personnel**

**3.3.1** Staffing for the maintenance group including selection of personnel shall be in accordance with Safety Guide on "Staffing, Recruitment, Training and Authorisation of Operating Personnel of NPPs", AERB/SG-01.

**3.3.2** All maintenance personnel (including outside personnel) shall be given training in radiological protection, safety rules, access control, emergency procedures appropriate to their duties, and they shall be adequately qualified in these areas before being allowed to work in controlled areas. Training in radiological protection shall be as per guide lines given in Safety Guide on Radiation Protection during Operation of NPPs. AERB/SG-05.

For special jobs, maintenance personnel should receive a special briefing appropriate to the job on the safety of plant, the related potential risks and consequent required safety precautions. Maintenance personnel shall also be appropriately trained and qualified in the quality assurance requirements applicable to their duties.

**3.3.3** Some of the maintenance personnel should be given special training, both at manufacturer's works and onsite, during construction, fabrication, assembly and testing of particular items important to safety.

**3.3.4** Maintenance technicians shall have adequate level of technical skill. Certain technical trades, such as welding, require periodic requalification to demonstrate that the individual continues to possess the necessary skills. For this purpose retraining may be necessary. They should also be trained to understand plant systems and equipment appropriate to their job. To provide flexibility in job allocation, technicians should be trained in several areas of the plant.

## 4. ADMINISTRATIVE CONTROLS

### 4.1 Procedures

**4.1.1** In order to supplement the maintenance programme, plant management shall establish administrative control through administrative procedures. Administrative procedures for maintenance shall be sufficiently comprehensive to provide plant maintenance personnel with administrative guidance in all areas of maintenance. The review and approval of administrative procedure shall be in accordance with safety guide on Quality Assurance during Commissioning and Operation of NPPs (AERB/SG/QA-5).

**4.1.2** The following is a list of some of the administrative controls and procedures to be taken into account when developing documents applicable to maintenance:

- (1) General maintenance work procedures
- (2) Generation and control of procedures
- (3) Review and revision of procedures
- (4) Work authorisation
- (5) Equipment isolation leading to work permit
- (6) Radiation work permit
- (7) Fire hazard control
- (8) Plant modification control
- (9) Training and qualification of maintenance personnel
- (10) Material and spare parts control
- (11) Lubrication control plan and schedule
- (12) Housekeeping and cleanliness
- (13) Personnel radiation monitoring
- (14) Equipment nomenclature, location and labeling
- (15) Preventive maintenance schedule
- (16) Maintenance instruction preparation
- (17) Shutdown work planning.

Information useful for developing authorisations, permits and certificates needed in administrative control of the tasks mentioned in items (4), (5) and (6) is provided in Annexure - I.

**4.1.3** In developing the above procedures, account shall be taken of the interfaces between one maintenance activity and other activities such as maintenance on other systems or components, plant operations and radiological protection. In particular the following aspects shall be explicitly covered:

1. Delineation of responsibility between those persons performing maintenance and those persons directly responsible for plant operation. For example, removal from and restoration to service of structures, systems and components shall be authorized by the Shift Charge Engineer.

2. Ensuring that during maintenance activity, operating personnel have adequate information about the status of equipment under maintenance.
3. The establishment of a work permit system controlling the issue and termination of appropriate documentation such as work authorisations, equipment isolation work permits, on-line testing authorisations, limitations of access etc. This includes designation of persons in the operating shift to issue such permits to those responsible for carrying out the work.
4. The provision of a direct positive indication of equipment that is not available for operation. This includes tagging where appropriate and any steps to be taken to prevent unintentional restoration to service. Tagging shall not obscure any indication device.
5. Ensuring that, after maintenance, the structure, systems and components are inspected for correct operational state and, where necessary, tested by authorised persons before their normal operation is resumed.
6. When work is to be undertaken in controlled areas, work planning and control requirements mentioned in the Safety Guide on Radiation Protection during Operation of NPPs, AERB/SG/05 shall be complied with.
7. Ensuring that appropriate dosimetric records are kept and assessed for each job involving radiation hazards, in order to help in future planning and to develop procedures which implement the ALARA principle.

## **4.2 Maintenance Instructions**

**4.2.1** The operating organisation shall require the plant management to prepare instructions that give detailed directions and controls required for carrying out maintenance. Plant management should delegate responsibility for preparing these instructions to the maintenance group. Instructions should be prepared in consultation with designer, equipment supplier and radiation protection personnel as necessary. If persons outside the maintenance group prepare the instructions for routine maintenance, they should be submitted to maintenance group for final approval. An administrative procedure shall describe the method, format and level of details required in the maintenance instruction. The preparation of maintenance instructions shall be in accordance with the Safety Guide on 'Quality Assurance during Commissioning and Operation of Nuclear Power Plants', AERB/SG/QA-5.

**4.2.2** Maintenance that can either affect the performance of items important to safety or potentially endangers the health and safety of personnel shall be preplanned and performed in accordance with written procedures, instructions appropriate to the circumstances.

Certain routine maintenance activities requiring skills normally possessed by qualified personnel may not require detailed step by step procedures, they shall nevertheless be subject to administrative control.



- 4.2.3 In exceptional cases maintenance can be authorised by designated persons after a review by plant management without written instructions initially available, with a provision that maintenance instructions are written and appropriately reviewed as the job progresses and approved on job completion.
- 4.2.4 In the process of preparing maintenance instructions, reference documents should be consulted to determine the technical content. These documents should include appropriate drawings, codes, standards, instruction books and manuals provided by the design organisation, construction organisation, equipment supplier and operating organisation.
- 4.2.5 Information in the instruction shall be presented in a logical, step-by-step order and all cross references to other relevant instructions shall be carefully reviewed and verified. The level of detail should be such that the individual responsible for the work can follow the instructions.
- 4.2.6 The content and format for a typical maintenance instruction should be generally in accordance with the Safety Guide on 'Quality Assurance during Commissioning and Operation of Nuclear Power Plant' AERB/SG/QA-5. The content should therefore include the following:
- (1) **Instruction Identification:** Numbers, letters or combinations of the two that identify each unique instruction as one in the maintenance series. They shall uniquely identify the instructions in all subsequent programmes, plans and records that refer to it.
  - (2) **Title:** A concise description of the subject of the instruction.
  - (3) **Purpose:** A brief statement of the scope of job controlled by the instruction.
  - (4) **Prerequisites:** All special conditions of the plant, system or equipment status required prior to commencement of work. Any special training or mock-up practice should be noted.
  - (5) **Limiting conditions:** Any conditions that limit plant operations as a result of carrying out the job such as load reduction and operation of standby equipment or safety systems. For example, when a system is undergoing maintenance it shall be considered unavailable for safety purposes unless it can be demonstrated that the ability of the system to perform its safety function has not been diminished.
  - (6) **Special precautions:** Special radiological protection measures, the need to secure or remove loose items and any required material control (e.g. incompatible lubricants or chemicals) and environmental conditioning.
  - (7) **Special tools and equipment:** Lists of all special tools, rigging and equipment required to perform the job.



- (8) **References:** List of applicable sections of reference documents that may need to be consulted such as, base line data, drawings, prints, instruction books, manuals, photographs, mock-ups etc.
- (9) **Instruction text:** A sequential step-by-step listing of work details required for the job and identifying any changes for radiological conditions as work progresses. At selected steps maintainer may be required to sign their names or initials certifying satisfactory completion of the preceding steps, either in the instruction or on an attached check sheet.
- (10) **Inspection witness points:** Selected points in work sequence where quality control verification is to be made. Work may not proceed past this point until the inspection has been made and documented.
- (11) **Verification of Operating Functions:** Operating function shall be verified jointly by both operating and maintenance personnel.
  - (11.1) **Return to Service:** Action and checks required to return the equipment or system to an operational condition after certification that the job is complete by the person responsible. Where appropriate, acceptance criteria shall be specified. These include correct reinstatement and correct procedural compliance as well as confirmation of system operability e.g: valve line up. All materials brought in connection with the maintenance work should be removed and the area should be thoroughly cleaned.
  - (11.2) **Operational testing:** Any post maintenance operational testing required to prove that the equipment is functioning in the intended manner.

**4.2.7** It is essential to document a brief but understandable review of the repairs carried out, explicitly identifying the cause of failure, the remedial action taken, the component that failed and its mode of failure, the total repair time and the outage time person-sievert and, finally the state of the system after repairs.



## **5. MAINTENANCE FACILITIES**

### **5.1 Workshop facilities**

**5.1.1** The operating organisation shall provide adequate workshop facilities with sufficient space and equipment to carry out maintenance effectively taking into account the need to deal with radioactive plant items. On-site workshops shall be provided for mechanical, electrical and instrument maintenance.

**5.1.2** Each of the workshops should include the following:

1. Office area, including facilities for the processing and storage of records and procedures.
2. Fitting and overhaul area with suitable work benches for dis-assembly, repair and reassembly of plant items that are intended to be dealt with in the workshop.
3. Storage facilities for special tools and testing equipment required for Maintenance.
4. Provision to prevent spread of contamination.

**5.1.3** On-site or Off-site facilities should include:

(1) Mechanical Shops

- (a) Space and equipment for welding, sheet metal fabrication, pipe fitting, and handling of heavy equipment and material with adequate provision for exhaust of cutting/welding fumes.
- (b) Machine tools such as lathe, milling machine, shaper, pedestal/radial drills, grinders and presses.
- (c) Clean room with lapping, polishing and surface checking equipment.

(2) Electrical shops:

- (a) Test benches with the appropriate power supplies connected.
- (b) Motor overhaul and test facility
- (c) Instrument and relay testing and calibration facilities
- (d) Rewinding facility

(3) Control and Instrument shops

- (a) Test benches with the necessary electrical, electronic, pneumatic and hydraulic supplies and test equipment.
- (b) Calibration and test facilities for instrument and control equipment.

#### 4. Other facilities:

- (a) Facilities for acceptance testing of overhauled/replacement equipment, as necessary.
- (b) Preventive maintenance tools such as vibration analysers, bearing monitoring tools and non-destructive testing facilities.
- (c) Carpentry and civil maintenance shops.
- (d) Material handling facilities.

### **5.2 Facilities for Maintenance of Radioactive Items**

**5.2.1** For the maintenance of irradiated and contaminated items, special maintenance facilities shall be provided in controlled areas to keep radiation exposure to individuals as low as reasonably achievable and to prevent the spread of contamination. Towards this end the following need consideration:

- (1) Access control and change rooms.
- (2) Ventilation with filtered discharge.
- (3) Treatment, handling and disposal of liquid and solid radioactive wastes.
- (4) Equipment for radiation monitoring and protection.
- (5) Shielding and remote handling equipment.
- (6) Provision for storing radioactive items, with non-conforming items segregated from conforming items.

#### **5.2.2 Decontamination Facilities:**

Operating Organisation shall provide facilities for removing radioactive contamination from plant items, tools. These facilities should include besides items 1 to 6 as in Sec. 5.2.1, the following:-

- (1) Decontamination tanks and special equipment to deal with the largest plant item likely to require decontamination prior to maintenance.
- (2) Adequate supplies of electrical power, steam, hot water, compressed air and approved chemical decontamination agents.
- (3) Ultrasonic decontamination systems.

### **5.3 Special Facilities**

#### **5.3.1 Mock-ups: (full or reduced size)**

In some cases there are maintenance advantages in designing and constructing simulation mockups or models of particular section of plant, either full size or reduced, locating them away from radioactive areas. Such facilities are particularly recommended for :-

- (1) Rehearsing work to be carried out in high radiation areas or on highly contaminated plant items, particularly for personnel not familiar with the plant or for an unusual or specialised job.
- (2) Preparing, and Validating procedures, to avoid errors and reduce exposure.
- (3) Gaining experience with tools and protective equipment in simulated working conditions.
- (4) Developing and improving tools and equipment.
- (5) Training and qualifying personnel for selected work.

### 5.3.2 Special equipment and tools:

Some special equipment that can significantly reduce radiation exposure should be provided. These include:-

- (1) Remote handling manipulators and special tools.
- (2) Automatic welding and cutting equipment.
- (3) Remotely operated non-destructive testing equipment.
- (4) In situ valve seat lapping machine.
- (5) Remote viewing equipment such as mirrors binoculars, telescopes, periscopes, boroscopes, fibroscopes, closed circuit television and remotely operated cameras.
- (6) Communication systems such as telephone, radio etc.
- (7) Special containers for contaminated equipment.
- (8) Shielded containers and portable shielding.
- (9) Radiological protection clothing and equipment.
- (10) Material and equipment for controlling and containing radioactive contamination, examples include plastic sheeting and tents, paper floor covering, suction cleaner and floor cleaning equipment;
- (11) Fixed or rapidly assembled access equipment to reduce personnel exposure, such as permanent ladders or telescopic ladders with cradles.

### **5.3.3** Photographic and Video records

**5.3.3.1** Photographic and Video records should be taken during the construction of plant areas which will become inaccessible subsequently. These should be comprehensively catalogued with description of the photographs and tapes. This will assist in work planning and familiarization before starting maintenance work. Photographic and video records could be prepared during certain major overhaul or activity for better clarity.

### **5.4** Lifting and Handling Facilities

**5.4.1** Plant management shall provide mobile lifting and transport facilities with clear indication of lifting capacity to handle equipment which needs removal and transportation. This will help reduce radiation exposure of maintenance personnel. To avoid radiological consequences due to failure of equipment, regular examination and maintenance, periodic testing and special inspection should be carried out on lifting equipment before major lifting and rigging operation.

## **6. REPLACEMENT AND REPAIRS**

### **6.1 Remedial Maintenance**

- 6.1.1** The need for remedial maintenance may arise when deficiencies or failure are noticed during plant operation. Procedures shall be established for (a) work authorization (b) work permit for equipment isolation (c) deficiency reports to maintenance group (d) withdrawal of plant items from service for remedial maintenance (e) operating personnel to assign priority to remedial work based on its importance to safety and operational limits and conditions.
- 6.1.2** After any remedial maintenance is completed, a brief report of the repair or replacement carried out should be prepared, identifying the component that failed, its mode of failure, the remedial action taken, the total repair time, the total outage time and the state of the system after the remedial maintenance work.
- 6.1.3** The maintenance group shall periodically review the maintenance records for evidence of incipient and recurring failures. On review, if there is a need for remedial maintenance the maintenance group shall initiate action in accordance with the procedure referred to in 6.1.1.
- 6.1.4** A defective item not suitable for subsequent repair shall be disposed off by a documented process that prevents its re-use. Defective components should not be allowed to accumulate in work areas.
- 6.1.5** Probabilistic Safety Assessment (PSA) methods can be gainfully employed for optimising the maintenance activities. PSA deals with the identification process and safety systems, maintenance actions, human errors etc. which are important to reactor safety. Based on the result of a PSA study, various maintenance importance measures of the systems e.g. Risk Achievement Worth, System Inspection Importance etc. can be evaluated for prioritisation of maintenance activities.

Reliability Centered Maintenance Methods further assist in obtaining the various failure mechanisms, modes, maintenance significant items and the efficacy of maintenance actions (preventive/predictive etc.) for an efficient risk based maintenance programme.

### **6.2 Repairing Defective Items**

- 6.2.1** Repairing defective items, whether removed from the plant or not, shall be done in accordance with established procedures. And this shall be done through equipment isolation work permits and work order authorization as appropriate.
- 6.2.2** When plant repairs consist of more than merely replacing parts and components by identical spares, a review shall be made as to whether the repair will involve changes sufficient to require application of the plant modification control procedure described in section 7.

- 6.2.3** If repairs are made in-situ, post maintenance functional/performance testing shall be carried out in conjunction with the operational personnel and results recorded. The plant item shall be returned to service or standby duty in accordance with established procedures by clearing the isolation work permits.
- 6.2.3** Plant items that have been repaired in the workshop shall be inspected and tested to ensure, as far as possible, full return to serviceability. If testing cannot be done in the workshop, cautionary labels or tags shall be applied to the plant item to warn that testing still has to be completed before reuse. When these post repair processes are complete, items not intended for immediate installation should be returned to Stores.



## **7. MODIFICATIONS OF STRUCTURES, SYSTEMS AND COMPONENTS**

### **7.1 Need for Modifications**

#### **7.1.1** Modification may be necessary to:

- (1) Rectify component failures discovered during maintenance
- (2) Repair components following failures in operation
- (3) Reduce the frequency of faults
- (4) Improve maintainability
- (5) Incorporate a non-identical replacement plant item
- (6) Replacement due to obsolescence.

**7.1.2** Need for modification may also result from experience in other plants, from new knowledge or from regulatory requirements. Modifications may affect structures, systems and components, operational limits and conditions, instructions and procedures or a combination thereof. Plant maintenance group may carry out approved modifications.

**7.1.3** Modifications of structures, systems and components shall satisfy the requirements detailed in section 16. of the Code of Practice on Safety in NPP Operation (AERB/SC/O). Safety Guides on Commissioning Procedures for PHWR based NPPs (AERB/SG/O-4) and Management of NPPs for Safe Operation (AERB/SG/O-9) may also be referred for further guidance.

### **7.2 Review Requirement**

**7.2.1** The operating organisation shall arrange for a first review of a proposed modification to ascertain if it affects safety. Where a proposed modification is judged to affect safety, a further independent review and assessment shall be carried out and the proposed modification shall then be submitted to the regulatory body for prior approval, if so required. In any case, when modifications of the operational limits and conditions are also involved, the proposed modification shall be submitted to the regulatory body for prior approval. In order to facilitate the first review, the operating organisation should specify those plant items and systems (such as primary coolant boundary, emergency electrical supplies, reactor protection equipment) that are considered in any case important to safety.

**7.2.2** The above mentioned directive should allow for rapid review and assessment of any proposed modifications that have to be undertaken urgently; nevertheless, such emergency action shall not reduce levels of safety. In these circumstances, retrospective formal documentation shall be completed without undue delay.

**7.2.3** Plant management shall issue modification control procedure clearly indicating responsibility for (a) co-ordinating plant modifications (b) classifying modifications as safety related or non-safety related (c) administering controls relating to the implementation and documentation and (d) disseminating information to specified bodies.

**7.2.4** Except when explicitly required by established procedures, the configuration of structures, systems and components important to safety shall not be altered (such as by defeating interlocks, installing jumpers, etc.) without written orders by authorised persons. In any case such alteration shall not violate operational limits and conditions. Any alteration shall be reviewed by competent persons as soon as possible and if alteration is considered to be of a permanent repetitive nature, appropriate approval of the regulatory body shall be obtained, if so required.

### **7.3 Submission of Proposals**

**7.3.1** Proposals for modifications submitted by plant management for independent assessment shall comply with requirements specified by operating organisation in accordance with quality assurance requirements. The submission shall specify the functional and safety requirements of the proposed modifications and show how these requirements are met. The amount of information needed will depend on the extent and complexity of the modification but, as a general guide, submission should include the following as necessary:

- (1) Design description and need for modification.
- (2) Safety analysis and proposed modification of the operating limits and conditions, if any.
- (3) Sketches, drawings and materials list.
- (4) Specifications requirements for parts and materials.
- (5) Applicable codes, standards and safety report section.
- (6) Fabrication, installation and test methods.
- (7) Operational state of the plant, or parts thereof, required to implement the modification.
- (8) Adverse environmental or operating conditions;
- (9) Quality assurance requirements.

**7.3.2** The proposal should demonstrate that the modification meets the original system specification or that the new system specification is distinctly an improvement over the previous specification.

## **7.4 Implementation and Documentation**

**7.4.1** All reviews and assessments shall be documented and only those modifications that have successfully gone through the appropriate process shall be approved for implementation. Implementation of modifications shall be subject to usual maintenance administrative procedures together with any special requirement generated by reviews and assessments.

**7.4.2** The plant management shall be responsible for recording approval and implementation of modification. They shall ensure the following:

- (1) Amendment of records of plant design as applicable.
- (2) Updating of drawings, procedures and instructions.
- (3) Disposing off of spare parts that do not conform and storage of new spare parts as per requirement no. (1).

## **8. STORES**

### **8.1 Organisation**

- 8.1.1** Stores-in-charge who is authorised to procure, receive, store and issue materials should be responsible to the Plant Management. The stores procedure shall clearly define who has the authority for specifying technical and quality assurance requirements and for selecting suppliers. Plant Management should identify items important to safety with appropriate quality assurance activities.
- 8.1.2** Maintenance group shall be responsible for ensuring that it has adequate spares, tools and resources to achieve specified objectives; it shall also be responsible for establishing stock levels and authorising issue of and use of spares.
- 8.1.3** Procedures shall be prepared as necessary for preservation, segregation and packaging to be applied during the storage of any item which has a shelf-life or is liable to deterioration in storage through exposure to air, moisture or other environmental factors. It shall be periodically verified that the conditions are met.
- 8.1.4** Stock rooms and storage areas shall be controlled to prevent the removal or replacement of material without appropriate documentation and authorisation.

### **8.2 Procurement**

- 8.2.1** Procurement of plant spares, materials, parts and components shall be in accordance with original specification and deviations however minor should not be permitted until the change has been referred to plant management for consideration under the procedure established for plant modification in Section 7 and duly approved by the plant management.
- 8.2.2** It should be the responsibility of the purchasing unit to ensure that materials and items are obtained only from reputed suppliers.
- 8.2.3** Routine re-ordering of material and plant items already held in store should be initiated automatically according to written procedures, when a predetermined lower stock limit is reached. This limit should be based on the expected or known rate of use and the anticipated delivery time and/or shelf life. The purchasing unit shall ensure, by means of documented reviews at the time of re-ordering, that the technical and quality assurance requirements have been updated as appropriate and incorporated in routinely generated procurement documents.
- 8.2.4** Procurement of maintenance items not held in store should be initiated by the maintenance group. This group should ensure with established procedure that the technical and quality assurance requirements are correctly established and specified to the purchasing unit. The purchasing unit should ensure that technical and quality

assurance requirements specified are incorporated into the procurement document without change.

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### **8.3 Receipts**

**8.3.1** Facilities for receiving on site all materials, spare & components for items important to safety should include:

- (1) equipment for safe and convenient handling
- (2) sufficient space with appropriate environmental conditions for storage
- (3) a separate and secure quarantine area for temporary retention of stores not cleared for final storage or issue
- (4) procedure to control the receipt and acceptance process
- (5) procedure for visual external inspection for transit damage
- (6) procedure for verification of correct packaging and identification

**8.3.2** Items found incomplete, incorrect or having inadequate documentation should not be accepted for final storage. Until nonconformance is resolved, it should be labelled or tagged "Awaiting Clearance".

### **8.4 Storage**

**8.4.1** Plant Management shall make administrative arrangements to provide adequate storage facility and to ensure that the storage facility is operated in a manner that preserves the correct environmental conditions, guards against fire hazard and prevents unauthorised access to stored items. The stored items should be arranged so that regular examinations of all stored items may be conveniently accomplished, where necessary, with suitable handling equipment.

**8.4.2** The administrative arrangements should include written procedure allocating responsibility for regularly examining stored items and auditing store administration to detect deterioration and unauthorised or unrecorded use of stored item. Particular attention should be paid to the retention of original identification of items during storage.

**8.4.3** In the procedure relating to modifications, plant management should include steps to initiate control and record the procurement of spare parts and plant items required as a result of modification, following modification to equivalent items installed in the plant.

### **8.5 Issue Requirements**

**8.5.1** Stored items shall be issued only by authorised persons in response to written orders presented by persons having authority to receive stored items. Appropriate records

should be generated to document the ultimate disposition of issued items to facilitate

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tracing them. The issuing procedure shall require that excess or un-used items be returned to stores in accordance with normal receipt practice. The procedure should permit emergency issue of urgently required stored items on the authority of and under the control of shift charge engineer, in a manner compatible with normal issuing process. While issuing stored items, it should be ensured that items received in stores first are issued first and old inventory does not get piled up. New arrivals should be stored accordingly for convenience of issuing items.



## **9. RECORDS**

### **9.1 Generation and Collection of Records**

- 9.1.1 Appropriate arrangements shall be made for orderly collection of records and production of reports on maintenance activities. Records and reports are required to provide objective evidence that the maintenance programme is being implemented fully in accordance with the quality assurance programme. In addition, maintenance records such as equipment history cards and the results of maintenance work are a necessary input to a continuing review of maintenance effectiveness on component reliability, which should be the responsibility of the maintenance group. In general, records shall identify the maintenance and operational personnel concerned and include certification by supervisors or quality control personnel as appropriate.
- 9.1.2 As mentioned above the Failure/Maintenance data collection should aid in proper assessment of the reliability of the component/equipment. Properly collected data would also help in carrying out more realistic plant PSA.

In order to carry out Reliability Analysis and PSA study of a plant, following input data is required

- (i) failure rate data
- (ii) repair rate/ down time data
- (iii) common cause failure data
- (iv) human error data.

The format for data collection should be organised in such a way as to obtain the requisite information including identification of failed component/system, failure mode and cause and effect on plant operation etc. A standardised format should be filled at all the operating plants to obtain a statistically significant data base and an idea about the variability of failure data. In view of the relatively large volume of data, it is imperative to have a computerised data collection and retrieval system. The analysis of such data would generate information regarding level of safety of an operating plant and design/procedure modifications required, if any, to enhance plant safety.

### **9.2 Retention of Records:**

- 9.2.1 The maintenance organisation should be required by an administrative procedure to select records that give a meaningful plant history and to retain them for the life of the plant. Other records that have only a transitory value should be retained either until they cease to serve the purpose for which they were originally intended or are replaced by later records. An important factor in selecting records is their use in assembling reliability data.
- 9.2.2 The records should consist of originals, hard copies, microfilms or computer storage. In all cases ease of retrievability commensurate with the likely need for consultation and review and the need to guard against accidental loss shall be taken into account when establishing storage facilities.





## **10. SURVEILLANCE, REVIEW AND AUDIT PROGRAMME**

### **10.1 Need for a Programm**

**10.1.1** The operating organisation shall establish a programme of surveillance, review and audit of maintenance in order to ensure that the maintenance programme has been implemented in accordance with the design intent, with regulatory codes and requirements and with the operating organisation's own procedures and policies. Reference should be made to AERB Code of Practice on Quality Assurance for Safety in NPPs (AERB CODE No. SC/QA), and Safety Guide on Quality Assurance during Commissioning and Operation of Nuclear Power Plants AERB/SG/QA-5.

### **10.2 Surveillance Programme**

**10.2.1** Verification of maintenance activities shall be carried out by appropriately qualified individuals who do not have direct responsibility for performing the maintenance work. Inspections may be unannounced and should include direct observation of the specific maintenance activity as well as examination of documentation. Results and findings of these inspection shall be transferred to the appropriate maintenance supervisor for corrective action, if any.

### **10.3 Review Programme**

**10.3.1** For impartial review of maintenance activities the review team may include department heads from plant management.

**10.3.2** The review programme should examine the maintenance programme for features such as:

- (1) Adequacy of preventive maintenance schedule and its implementation,
- (2) Response to remedial maintenance requirements,
- (3) Satisfactory control of radiation doses,
- (4) Effective use of resources,
- (5) Level of training experience,
- (6) Adherence to quality assurance requirements,
- (7) Adequacy of procedures and instructions.

**10.3.3** The findings of the review programme should be reported periodically to the maintenance group, plant management and designated members of the operating organisation.

### **10.4 Audit Programme**

**10.4.1** The audit shall be performed by qualified personnel who have no direct responsibility for maintenance at specified intervals. Audit shall be in accordance with Safety Guide on Quality Assurance During Commissioning and Operation of NPPs AERB/SG/QA-5 and shall cover all areas of the maintenance activity that could affect items important to safety.

## **11. FEEDBACK OF EXPERIENCE**

- 11.1** Maintenance experience data collection and analysis are necessary in order to enhance the safety of the plant and reliability of structures, systems and components throughout their operating life. Not only significant events, but also minor incidents, may reveal important deficiencies or negative trends adverse to safety.
- 11.2** Therefore, a process for collecting, classifying and evaluating abnormal events or findings concerning maintenance, and for feeding back the results of the lessons learned from experience into the design and operation of power plants is considered to be of paramount importance.
- 11.3** The operating organisation shall arrange for:
- (1) Collecting, evaluating, classifying and recording abnormal events or findings, in order to detect precursors, common mode failure mechanisms, deficiency of equipment or personnel;
  - (2) Transferring to the design groups the experience of actual maintenance in order to enable designers to improve plant features in existing or up coming plants which have a bearing on the maintenance activity, such as ease of access, ease of disassembly and reassembly, and implementation of ALARA principle;
  - (3) Utilising maintenance experience in the training of maintenance personnel;
  - (4) Validated reliability data to be used for probabilistic safety assessment and for technical specification of new components;
  - (5) Ensuring retrievability of data and proper transfer of the relevant information to the appropriate persons or organisations.



## ANNEXURE I

### ADMINISTRATIVE ASPECTS OF MAINTENANCE WORK

#### AI-1 General

**AI-1.1** This annexure is intended to provide information useful for preparing authorisations, permits and certificates needed in administrative control to ensure safety in the work area and to prevent maintenance activities from affecting other aspects of safety. It deals specifically with the items listed in sub-section 4.1.2 of this Guide, namely:

Item (4) Work authorisations

Item (5) Equipment isolation leading to work permits

Item (6) Radiation work permits

and it also addresses those aspects of item (7), fire hazard control, and item (8), plant modification control, which are inseparable from the above items.

**AI-1.2** These authorisations, permits and certificates generally:

- (1) Define the plant item, the type of work to be performed, and the boundaries of the working area in which the activities of the plant personnel are authorised.
- (2) Confirm that the plant item is either in safe condition to work on, or conforms to conditions set out in the prerequisites of written procedures appropriate to the authorised work. These conditions should specify precautions that need to be taken.
- (3) Confirm radiological conditions in the work area, note any other possible hazards, and specify precautions to be taken in order that the authorised work may be carried out.
- (4) Confirm that all personnel have been withdrawn from the work area after the authorised work is completed and the plant item can either be returned to service or remain in a specified condition.
- (5) Include self-cancellation features by indicating the conditions of validity, e.g. time limits.

**AI-1.3** This annexure does not relate to controls required to avoid incorrect maintenance of the plant item. These are covered in section 4.2 (Maintenance Instructions) which should be considered together with associated quality assurance requirements covered in the Safety Guide on Quality Assurance during operation of Nuclear Power Plants, AERB/SG/QA-5.

## **AI-2 Work Order Authorisation**

**AI-2.1** Items to be considered in the preparation of work order authorisation are as follows:

- (1) Procedures to obtain authorisation for undertaking maintenance, repair, replacement or modifications.
- (2) Means to ensure that the work is not undertaken to modify the plant unless the modification has been authorised according to the approved procedures (see section 7).
- (3) Unambiguous identification of plant items on which work is authorised. This requires a clear, unambiguous labeling system, particularly for multiple unit plants.
- (4) Description of the work to be undertaken. This may be by reference to the appropriate procedure which describes the scope of work, pre-requisites, precautions, post-maintenance testing requirements etc, as detailed in sub-section 4.2.4 of this Guide or by reference to the document describing the approved plant modification.
- (5) Procedure to ensure that both the boundaries of the work area and access through them are specified and clearly marked. This includes locking, barring, taping or roping off unauthorised access routes such as doors, windows or manholes and confirmation that the specified action has been taken.
- (6) Necessity for the person authorising work to know all other relevant work which is being undertaken on the plant, so that account can be taken of any interference between the work described in the authorisations and the work covered by other authorisations.
- (7) Cancellation/termination of authorisation:
  - i) by a person authorised to do so, or
  - ii) after expiry of a stated time, or
  - iii) under stated conditions (e.g. non-validity of relevant radiation work permits, or shift change-over).

## **AI-3 Equipment Isolation Work Permit**

**AI-3.1** The following list contains items to be considered in the preparation of equipment isolation work permits to ensure a particular plant item is safe to work on or it is otherwise in accordance with the specified pre-requisites for the work to be undertaken. Some of these details may need to be considered in the preparation of work order authorisations, even if isolation of a plant item is not necessary:

- (1) Specification of a plant item and the required conditions (earthed, isolated, vented, jumpered, etc) under which authorised work is to be performed.
- (2) Control of activities that may either change radiological conditions in the work place while work is in progress, or change conditions related to other hazards ( e.g. release of steam or gases pressure build-up).
- (3) Establishment of key interlock procedures.
- (4) Identification of the state of the plant items by the use of stamps, tags, labels, routing cards etc.
- (5) Confirmation of specified actions taken.
- (6) Authorisation by shift engineer for any plant item to be taken out of service or restored to service, documentation of the change-over of responsibility from one shift to the next.
- (7) Assurance that removal of one or more plant items from service for maintenance conforms with the requirement of plant operational limits and conditions (see the Safety Guide on Operational Limits and Conditions AERB/SG/O-3).
- (8) Cancellation of permit by an authorised person:
  - i) after expiry of a stated time, or
  - ii) under other stated conditions, or
  - iii) by cancellation of work authorisation.

#### **AI-4 Radiation Work Permit**

**AI-4.1** The following list contains items to be considered in the preparation of radiation work permits, (a) to establish the radiological conditions under which authorised work may be undertaken, and (b) to specify the precautions to be taken:

- (1) Clearance for a radiological survey to be carried out by a qualified health physicist so that radiation and contamination levels can be checked and certified before a work permit is issued. This clearance would specify the extent of the survey to be undertaken, any special conditions and any hazards other than radiological hazards to which the person performing the survey may be exposed.
- (2) Identification of the radiation hazards and the precautions to be taken. This may be done by classifying radiation and contamination zones (see the Safety Guide on Radiation Protection AERB/SG/O-5), marking the radiation and contamination levels in the area where the work is to be undertaken, identifying

the boundaries of these zones, confirming that a radiological survey has been carried out, and specifying the access of the area for normal and emergency use. In addition, other appropriate precautions, such as provisions of equipment isolation, may need to be taken.

- (3) Individual and collective dose limits for the work authorised.
- (4) Precautions (specified when appropriate by a certified health physicist) that may need to be taken before, during, or on work completion in a radiation or contamination zone. These include:
  - (i) Monitoring requirements and the frequency of radiological surveys to be performed during the work.
  - (ii) Types of personal dose meters to be worn.
  - (iii) Shielding, ventilation, decontamination and waste handling requirements.
  - (iv) Protective clothing and respiratory equipment.
  - (v) Special precautions, such as specifying a reference level in terms of a QFE (quartz fiber electrometer) - direct reading dosimeter - reading which shall not be exceeded.
  - (vi) Hold points to evaluate progress of work in order to establish whether conditions are acceptable for work to continue to the next phase of work programme.
  - (vii) Automatic invalidation of permits after a specified time interval.
- (5) Monitoring of individual and collective doses and comparison with relevant limits at the time of hold points and on work completion.
- (6) Cancellation of permit:
  - (i) by a person authorised to do so, or
  - (ii) after expiry of a stated time, or
  - (iii) if a given reference level is exceeded, or
  - (iv) under stated conditions (e.g. shift change-over), or
  - (v) by cancellation of work authorisation.



**AI-5 Covering Conventional Hazards in Work Permits**

**AI-5.1** Safety standards for nuclear plants require careful attention to conventional hazards that can exist in work places. For this purpose a designated person should authorise the work taking into account the conditions and precautions against conventional hazards examples include:

- (i) Monitoring the presence of combustible, toxic and asphyxiating gases and specifying action levels.
- (ii) Protection against spark or flame producing activities such as welding.
- (iii) Protection if internal combustion engines, electrical machines, or combustible materials are to be used.
- (iv) Ensuring visibility.
- (v) Protection against hazardous fluids.
- (vi) Operating or tripping ventilation system.
- (vii) Adjustment of automatic fire extinguishing systems where these may create a hazard in the work place or its access routes.

**AI-6 Certification of Work Completion:**

**AI-6.1** In developing certificates of work completion, the following consideration should be taken into account:

- (1) Confirmation from the maintenance engineer that the authorised work has been satisfactorily completed. Provisions should be made for this confirmation to be given for deviations from the originally authorised work provided these are in accordance with written procedures that cover approval for such deviations.
- (2) Either acceptance by the shift supervisor of the plant item for operation (or standby in readiness for operation), or acknowledgment of the condition in which it is to be left.
- (3) Acceptance of conditions in the work area after it has been vacated.
- (4) Confirmation that all relevant authorisations and permits have been cancelled and all copies are so marked.
- (5) Clear definition of responsibilities for post- maintenance testing. This includes responsibility for live testing, since this is an interface activity between operations and maintenance personnel. This could for example,

include confirmation by the maintenance engineer that the item is safe for testing under specified conditions.

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**AI-7      Format and Documentation Control:**

**AI-7.1**      The following list contains items to be considered in the design and layout of authorisations, permits and certificates:

- (1)      Unambiguous allocation of responsibilities, by the inclusion of features providing, inter alia, a clear indication that the persons issuing, receiving or cancelling a permit (or authorisation) are authorised to do so.
- (2)      Provisions of space at appropriate locations for signatures.
- (3)      An unambiguous means of showing the conditions to be observed, the precautions to be taken and the completion of these actions. This can be achieved using signed check lists.
- (4)      Routing of copies to be such that the shift charge engineer on duty is aware of all relevant work on the plant.
- (5)      Authenticity of forms and means of documentation control (the name of the operating organisation, the nuclear power plant unit, a unique form of reference, colours and copy number).

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## LIST OF PARTICIPANTS

### Advisory Committee on Codes, Guides and Associated Manuals for Safety in Operation of Nuclear Power Plant constituted by AERB.

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**PROVISIONAL LIST OF GUIDES ON  
OPERATION OF NUCLEAR POWER PLANTS**

<b>Safety Series Nos.</b>	<b>Provisional Title</b>
AERB/SG/O-1	Training and Qualification 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 Heavy Water Based NPPs
AERB/SG/O-5	Radiation Protection during Operation of NPPs
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AERB/SG/O-10	Core Management and Fuel Handling for NPPs
AERB/SG/O-11	Operational Management of Radioactive Effluents and Wastes Arising in NPPs

**NOTES**





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