
**GOVERNMENT OF INDIA**

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**AERB SAFETY GUIDE**

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# COMMISSIONING PROCEDURES FOR PRESSURISED HEAVY WATER REACTOR BASED NUCLEAR POWER PLANTS

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**ATOMIC ENERGY REGULATORY BOARD**

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**AERB SAFETY GUIDE NO. AERB/SG/O-4**

# COMMISSIONING PROCEDURES

# FOR

# PRESSURISED HEAVY WATER REACTOR

# BASED NUCLEAR POWER PLANTS

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

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**Orders for this Guide should be addressed to :**

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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 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 appendices included in the document are considered to be an integral part of the document, whereas the annexure, foot-notes and bibliography 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.

The Code of Practice on Safety in Nuclear Power Plant Operation states the minimum requirements to be met during the operation of thermal neutron reactor based power plants in India. This safety guide provides guidance for the commissioning procedures for pressurised

heavy water based nuclear power plants in india. While elaborating the requirements stated in the Code of Practice on Safety in Nuclear Power Plant Operation, it provides necessary information to assist personnel and organisations participating in the commissioning of Nuclear Power Plants.

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 developed by the International Atomic Energy Agency (IAEA) under the Nuclear Safety Standards (NUSS) programme, expacially the Safety Guide on Commissioning Procedures in Nuclear Power Plants (No.50-SG-O4, 1980).

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**[1]

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**[2]

All operational processes deviating from normal operation which may occur during the operating life of the plant and which in view of appropriate design provisions, neither cause any significant damage to items important to safety nor lead to accident conditions.

**Approval**

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

**Atomic Energy Regulatory Board (AERB)**

A national authority designated by the 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**[3]

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

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

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

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

**Authorisation**[4]

See ' Regulatory Consent'.

**Commencement of Operation**[4]

The beginning activity/activities towards first approach to criticality.

**Commissioning**[5]

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

**Construction**[5]

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

**Decommissioning**[5]

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

**Emergency Situation**

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

**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.

**Full Power**

Full power is the rated thermal power of the reactor, i.e., the gross fission power as established by station heat balance using approved methodology.

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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.

**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.

**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.

**Operating Organisation[6]**

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

**Operation**

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 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.

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6 Organisation structure and not individual names.

**Prescribed Limits**

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

**Protection System**

A part of safety critical system which encompasses all those electrical and mechanical devices and circuitry, from and including the sensors upto the input terminals of the safety actuation systems involved in generating the signals associated with the safety tasks.

**Qualified Person**

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

**Quality Assurance**

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

**Records**

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

**Regulatory Consent**

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

**Reliability**

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

**Responsible Organisation**[7]

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

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7 In the present context the Nuclear Power Corporation of India Limited (NPCIL) is the responsible organisation for nuclear power plants in india.

**Safety**

Protection of all persons from undue hazard.

**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.

**Site Personnel**

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

**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.

**Testing**

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.

# CONTENTS

# 1. INTRODUCTION

## 1.1 General

1.1.1 This Safety Guide supplements commissioning requirements mentioned in the Code of Practice for Operation of Nuclear Power Plants (AERB/SC/O) which states "The commissioning programme shall assure that after construction, the NPP is made operational in a systematic, informative and safe manner. The programme shall verify that the performance criteria, design intent and QA requirements are satisfied. It shall demonstrate that the plant can be operated in a safe manner through integrated testing of the plant system". This guide elaborates the general steps to meet the requirement of the Code. The provisional list of other Guides on Operation is also given at the end of this publication.

1.1.2 Carefully planned and executed commissioning is essential to the subsequent safe operation of the plant. Accordingly, a detailed programme of tests is prepared, and the responsibility for implementing and reporting on the various parts of the commissioning programme is clearly defined. The commissioning programme shall be submitted for the approval of the Regulatory Body. Close liaison shall be maintained between Regulatory Body and the Operating Organisation throughout the development and implementation of the whole commissioning programme.

## 1.2 Objectives

1.2.1 The commissioning activities should be performed in a proper sequence. In carrying out commissioning, the aim is to verify the proper installation of structures, systems and components and their instrumentation, starting with the acceptance of installed components, moving on to the testing of individual systems and progressing to integrated system tests, until the safe operation of the nuclear power plant as a whole is finally proved. This will also enable the operating personnel to become familiar with operating characteristics, the proposed operating and maintenance procedures and periodic tests; and they should also demonstrate the adequacy of these procedures and tests for safe operation of the plant. Commissioning procedures should also establish baseline or reference data for future reference.

1.2.2 Commissioning is the process by which plant components and systems, having been constructed, are made operational and verified to be in accordance with design specifications and to have met the performance criteria; it includes both nuclear and non-nuclear tests.

## 1.3 Scope

1.3.1 The scope of this Guide covers all aspects of commissioning programme of PHWR-based NPPs. It includes organization and management, test and review procedures, and the interfaces between construction, commissioning and operating activities at the site. It also covers the control of the documentation required during commissioning. The aspects of interface between plant management and other agencies such as Design, Quality Assurance and Regulatory Body required during Commissioning are covered in AERB/SG/O-9. AERB/SG/O-9 may also be referred to for additional guidance.

## 2. COMMISSIONING PROGRAMME

### 2.1 General

2.1.1 A commissioning programme is required to enable assurances to be given that the plant will be commissioned in a safe, systematic, efficient and informative manner.

2.1.2 The programme shall be established and implemented to demonstrate that the requirements of the design as stated in the safety report are met, and should indicate the principal points where reviews are required to satisfy both the responsible organization and the Regulatory Body.

2.1.3 The programme should provide a framework for the scheduling of tests and related activities, and for suitable personnel and equipment to be available at the proper time. The programme should also provide for the timely preparation of all documentation.

2.1.4 In case of identical units of standardised design in a multi-unit NPP, it may be possible to forgo a few selected tests from those already performed for the previous units. The operating organization should ensure that such action does not jeopardize safety and is taken only with prior approval of the Regulatory Body.

2.1.5 If, in multi-unit NPPs, some of the structures, systems and components are common to more than one unit, tests should be conducted to provide assurance that the specified performance requirements of these structures, systems and components can be met.

2.1.6 Special tests for 1st proto type unit/system should also be planned and conducted. Examples include static reactivity worth of shut down systems, ECCS, capability of core residual heat removal by natural convection cooling etc.

### 2.2 Format

2.2.1 The programme should be written in such a format as to enable the objectives and methods of testing to be understood and to allow management control and co-ordination to take place.

2.2.2 The commissioning programme should list all the tests and related activities in their sequence. Each test should be covered by a detailed procedure to include the following [13]:

1. The purpose of tests, the results expected under test conditions, the acceptance criteria, and their relevance to the proposed operational limits and conditions where applicable. The title and number of each test should have unique identification.

2. The pre-requisites for each test should be clearly specified which should include requirement of man power and special equipment.

3. The interdependence of test procedures by giving suitable cross reference to other documents relevant to commissioning.

4. The points at which Regulatory Body reviews are required to obtain necessary clearances to proceed further (hold points). These specifically refer to the regulatory clearances for the following :

   a) PHT hot conditioning
   b) Initial core fuel loading
   c) Heavy water addition to the moderator system
   d) First approach to criticality and low power physics experiments ( < 0.1 % F.P.)
   e) Initial power raising & synchronisation with grid upto 50 % F.P.
   f) Power operation typically at 50 %, 75 %, 90 % & 100 % F.P or at power levels stipulated by the Regulatory Body based on review of performance.

5. The minimum technical and administrative provisions and safety precautions required during the test.

6. Any applicable requirements of AERB including the witnessing of specified tests (witness points).

7. Special testing equipment required at various stages of testing.

2.2.3 The programme should be divided into suitable phases. The programme should show the planned duration of the activities and their inter-relation with one another. The programme should include activities that may be required in order to provide opportunities for the operating personnel to gain familiarity with the operation of the plant.

**2.3 Review**

2.3.1 An internal review by the Operating Organisation of the procedures and the test results is done to ensure that the performance is in accordance with design intent. It should ensure that all required data have been obtained and analysed and that a technical evaluation report has been completed.

2.3.2 Personnel assigned to carry out reviews shall possess adequate experience in their respective specialities and should not have direct responsibility for the performance of activities under their review. Whenever consultants are utilised, the overall responsibility shall continue to rest with the operating organisation.

# 3. PRINCIPAL PHASES OF COMMISSIONING

## 3.1 General Principles

3.1.1 The commissioning programme shall be divided into the following phases :-

Phase A: Pre-operational commissioning tests.
Phase B: Fuel loading, heavy water addition, initial criticality and low power tests (upto 0.1% of FP)
Phase C: Power tests (from 0.1 % to 100 % FP)

To proceed from one phase to the next, AERB clearance shall be obtained by the plant management (for more details refer [13]).

The concerned organisation may introduce sub-phases where the sequence within a phase has substantial safety significance. Each phase and sub-phase should be followed by a review before the next phase/sub-phase is started. The phase C should, in general, be limited to those tests which can only be carried out at power. A general sequence of major commissioning steps is given in Figure-1 and list of tests to be considered for inclusion in commissioning programme is given in Annexure 1.

3.1.2 The sequence of tests within each sub-phase should be given in chronological order in which they are expected to be performed.

3.1.3 To the extent practicable, the tests should be of sufficient duration to allow the systems and components to reach their normal equilibrium conditions, thus reducing the probability of failure during early plant life.

3.1.4 At appropriate commissioning stages, alarm and trip settings of protective and process systems instrumentation including radiological protection should be adjusted.

## 3.2 Phase A : Pre-operational tests

3.2.1 Before the commencement of Phase A, it is necessary to review and complete certain prerequisites for which the construction group is responsible (see Sub-Section 5.2.2).

3.2.2 **Phase A comprises following sub-phases**

A-1: Cold performance tests
A-2: Hot performance tests

These tests are discussed in Sub-Sections 3.2.3 & 3.2.4 and shall be carried out as per written procedures.

3.2.3 **Cold Performance Test (sub-phase A-1)**

3.2.3.1 If pressure test of certain components/systems is not carried out before transfer of the system to the commissioning group, it shall be carried out as part of the commissioning programme. In addition, physical check of completeness of system erection and layout as per design drawing is carried out. System components/equipment and piping is cleaned by appropriate flushing/recirculation.

3.2.3.2 Cold performance testing is performed to obtain initial operational data of equipment, compatibility of operation with interfacing systems and verification of the functional performance of these systems.

3.2.3.3 It may be desirable to do the initial commissioning of primary heat transport system and moderator system using light water instead of heavy water.

3.2.4 **Hot Performance Test**

3.2.4.1 These tests shall follow cold performance tests, simulating as far as practicable plant operating conditions, including anticipated operational occurrences at typical temperatures, pressures and flow rates.

3.2.4.2 These tests shall, to the extent possible verify the effectiveness of thermal insulation and heat removal systems. They will enable initial checking of flow rates, vibration, clearances and other provisions made for accommodating expansion of components or systems. The operation of instruments and other equipment at high temperature shall be verified and the relevant operating techniques confirmed.

3.2.4.3 In primary heat transport system, hot conditioning of carbon steel piping is done to obtain a corrosion resistant adherent coating of magnetite on the internal surface of the piping.

3.2.4.4 The duration of hot performance testing shall be such that a steady state operating condition is achieved, in order to determine whether the structures, systems and components are operating according to specifications.

3.2.5 After successful completion of above tests, draining of light water, drying and filling of cover gas system is carried out in moderator and PHT system.

**3.3 Phase B: Fuel Loading, Heavy Water Addition, Initial Criticality and Low Power Tests**

3.3.1 **General:**

3.3.1.1 Since the initial fuel loading together with heavy water addition results in the commencement of operation, the relevant radiation safety requirements including radiological protection procedures for plant operation shall apply from this point onwards.

3.3.1.2 The purpose of phase B is to confirm that the reactor is in a suitable condition to start up for power operation and that the characteristics of core coolant, operation of reactivity control systems, reactor physics parameters, and shielding as appropriate, are satisfactory. During this phase, the reactor power is limited to below 0.1 % of full power. This phase is expected to avoid significant irradiation of fuel and activation of reactor components to help maintain low radiation background. The information obtained from these tests shall ensure that no fundamental disagreement exists between the measured reactor physics parameters and those used in the safety report, thus permitting power testing.

3.3.1.3 **Phase B comprises the following**

B-1 1) Fuel Loading ;
2) Flushing of moderator system with heavy water and addition of specified quantity of borated heavy water ;
3) Addition of heavy water to PHT system;
4) Bulk addition of heavy water to moderator system ;

B-2 5) Initial criticality ; and
B-3 6) Low power tests.

3.3.2 **B-1 : Fuel Loading, Heavy Water Addition**

3.3.2.1 While initial fresh fuel loading into the reactor coolant channels may be done manually, satisfactory capability for fuelling/refuelling of the reactor core using normal fuelling machines and associated fuel transfer system should be demonstrated at least upto rehearsal facility before approach to initial criticality. Appendix A gives further guidance on fuel loading and heavy water additions.

3.3.2.2 (1) Fill PHT system with heavy water as per written procedure. Recirculate and take sample to ensure isotopic purity and pH are as per specification.

(2) After fuel loading, PHT performance test is undertaken to confirm the coolant flow characteristics in flow monitored channels.

3.3.2.3 Fill moderator system as per written procedure with heavy water containing neutron absorbing material added to it to ensure that reactor remains sub-critical even in the event of PHT system heavy water leaking into moderator system. Ther purification system shall be kept isolated.

3.3.2.4 Sequence of activities of `fuel loading' or bulk addition of heavy water in moderator system can be altered depending on situation. However, before taking up the operation, conditions specified in Appendix A should be met.

3.3.2.5 Before approach to criticality is started, operability of the automatic reactivity shutdown devices shall be ensured and appropriate start up monitoring instrumentation made be available to initiate the shutdown devices.

3.3.2.6 Start up neutron monitoring instruments should be calibrated before approach to criticality, and the required minimum neutron count rate shall be obtained. Trip set points shall be reduced to a minimum level compatible with the need to prevent spurious tripping.

3.3.2.7 Steps shall be taken to ensure that the start up proceeds in a safe and orderly manner. For this purpose, changes in neutron count rate shall be continuously monitored and interpreted so that the prediction of the point of criticality is continuously checked, and the reactivity change is controlled by adjusting the adjuster positions and concentration of neutron absorbing material in the moderator and/or moderator level adjustment.

3.3.2.8 The procedures for achieving criticality shall require an increasingly cautious approach. There should be continuous predictions of the point of criticality and addition in reactivity made finer/smaller as the point of criticality is approached (to avoid passing through the point of criticality with a short period). After criticality is achieved the rate of flux increase (period) shall be restricted to permissible value and the reactor regulation transferred to auto-control as soon as possible after reactor flux exceeds 107 neutrons/sec. All these operations are carried out under the guidance of the reactor physicist.

3.3.2.9 The purpose of low power tests is to confirm that the reactor is in a proper condition for operation at higher levels, and that the characteristics of the core reactivity control systems, reactor physics parameters, and shielding as appropriate, are in accordance with design predictions. These tests are done after reactor regulation is transferred to `auto control'.

3.3.2.10 Power should be maintained at sufficiently low levels, as indicated in sub-section 3.3.1.2.

## 3.4 Phase C : Power Tests

3.4.1 Phase C consists of raising reactor power beyond 0.1% full power (F.P.) in a step-by-step approach to full power and full power tests. At each sub-phase a series of tests will be carried out at specified power levels. Typical steps may be 50%, 75%, 90% and 100% of full power.

3.4.2 Full power tests are intended to confirm that the plant can be operated in accordance with design intent and that plant operation can be continued in a safe manner. Tests which are required to demonstrate safe operability shall be completed promptly.

3.4.3 Tests shall demonstrate, to the extent practicable, that the plant operates in accordance with design both during steady state conditions and during and after anticipated operational occurrences including reactor trips and load rejections initiated at suitable power levels.

3.4.4 The review at the end of the stage shall confirm whether the operational limits and conditions are adequate and practicable, and shall identify any constraints on the operation of the plant which the commissioning tests have shown to be necessary.

# 4. TESTING PROCEDURES

## 4.1 General

All commissioning tests shall be performed in accordance with approved procedures. In cases where procedures are required to be submitted to the regulatory body for authorisation/approval, this shall be done and authorisation/approval be obtained before to implementing the procedure. Changes if any, involving safety shall also be submitted to the regulatory body for prior approval. Each authorised test procedure should carry a unique means of identification, including a comprehensive cross reference to other associated documents and a distribution list.

## 4.2 Procedure Contents

4.2.1 The test procedures should follow the normal plant operating procedure to the extent practicable. The procedure shall state deviations from the design or normal operating configuration before the test and checks to ensure that systems and components are restored to their normal status after the tests are over. Consistent with safety requirements, consideration shall be given to ensure that deviations from normal functioning do not invalidate the test objectives.

4.2.2 Test procedure shall include the following information:

1. **Introduction :** A summary of the main test objectives and the safety aspects to be demonstrated in relation to the stages of the main commissioning programme;

2. **Test Objectives and Methods :** Objectives of the tests and the methods by which they will be achieved should be stated;

3. **Limiting Criteria :** Applicable operational limits and conditions;

4. **Pre-requisites & Initial Conditions :** The state of all relevant systems which are likely to affect or be affected by the system under test shall be given together with conditions and precautions, if any, needed to maintain the desired system configuration;

5. **Tests Conditions and Procedures :** The way in which the system to be tested shall be brought up to test conditions and details of the test procedure by a step by step format;

6. **List of Instrumentation & Special Test Equipments :** Any special test equipment and calibrations required shall be specified;

7. **Acceptance Criteria :** Qualitative and quantitative details of acceptance criteria finalised in consultation with the designers;

8. **Manpower Requirements, Qualifications and Responsibilities :** Manpower requirement, qualifications and assignment of duties and responsibilities for conducting tests;

9. **Special Precautions :** Special precautions for the safety of personnel and equipment;

10. **Test Completion :** Certification on satisfactory completion of tests and systems returned back to normal operating conditions;

11. **Test Data and Records :** Collection of baseline data including information that are to be kept on permanent records is approved as per the approved tabulated format; and

12. **Identification, Referencing and Distribution :** Unique identification of test procedure, cross reference and distribution list.

## 4.3 Test Results

4.3.1 Data Collection

Test data should be recorded chronologically in standardized forms of test sheets. It should be signed by the data collector.

4.3.2 Processing and Evaluation

Processing and evaluation of the test data shall be carried out to confirm that the test objectives have been achieved and that no unexpected features have arisen. The evaluation of test results shall include a comparison with the acceptance criteria.

## 4.4 Reporting

4.4.1 The commissioning group should report the test results to the operating organisation and, as required, to the other participants in the commissioning programme. While interim reports may be prepared soon after the tests to enable quick assessment of the results, a final comprehensive report shall be submitted containing all information including a collation and final evaluation of the test results. The reports should be vetted by the appropriate design sections/groups.

4.4.2 Final reports should be prepared and signed by the individuals responsible. The report includes :

1. Introduction ;
2. References to appropriate test procedures ;
3. Summary of test objectives ;
4. Conduct of the test, including initial and final state of the plant, the actual limitations experienced, problems encountered and actions taken to overcome them, including modifications to the plant or procedures arising therefrom ;
5. Concise description of any special test equipment used ;
6. Summary of data collected and analyses thereof ;
7. Evaluation of results ;
8. Conclusions ; and
9. Identification, cross references and distribution list (See 4.2.2(12)).

## 4.5 Approvals and Issue of Certificates

4.5.1 Documents should be prepared and issued during the progress of the commissioning activities to certify the performance of the tests and provide phase clearances for the continuation of commissioning programme. AERB's approval shall be obtained when clearing major phases indicated in sub-section 3.1.1 as specified by AERB.

4.5.2 Test certificates are issued to certify that the test has been completed in accordance with authorized procedures or it shall state any reservations, departures from or limitations of these procedures.

4.5.3 Phase completion certificate is issued to certify that all the tests in commissioning the respective phase have been satisfactorily completed (listing all deficiencies, if any). It should also list associated test certificates.

4.5.4 A change notice is an intimation of modification of previously approved test procedures.

4.5.5 Final report can also serve as valid test/phase completion certificates (see sub section 4.5.2) provided they contain all the required information.

4.5.6 To ensure that commissioning programme proceeds in an orderly manner, suitable preparations need to be made so that phase completion certificates and documents to obtain authorisation can be produced expeditiously. To this end, reviews of test results need to be undertaken and test results accepted at suitable times during the progress of testing within each phase; the end of each phase should include preparations for the next phase; and means should be arranged for continual updating of documentation (including as-built drawings). A close liaison should be maintained with all participants in the commissioning programme including those at the operating organisation headquarters and personnel of the Regulatory Body.

## 4.6 Modifications

4.6.1 Consequent on commissioning of systems, any change/ modification in the system if need be, should be carried out only after prior approval of operating organisation. Approval of AERB is required on changes/modifications which affect the logics of safety system operation and/or in technical specifications.

# 5. ORGANIZATION, RESPONSIBILITIES AND AUDIT

## 5.1 Organization

### 5.1.1 General

5.1.1.1 The Responsible Organization authorized by AERB to operate the plant, shall be the overall controlling and co-ordinating authority to oversee satisfactory completion of all commissioning work (see Figs. 2A, 2B & 2C).

5.1.1.2 The principal activities of construction and installation of the plant, commissioning and operation of the plant are entrusted to the construction group, commissioning group and operating group respectively.

5.1.1.3 The construction group ensures that the installation has been completed in accordance with specifications. The commissioning group ensures that structures, systems and components are tested to ensure that the plant has been properly designed and constructed and is ready for safe operation. The operating group operates systems and the plant in accordance with the commissioning programme. This facilitates the operations group to become familiar with the plant and facilities, starting from the commissioning phase itself.

5.1.1.4 Apart from the groups indicated in sub-section 5.1.1.2 designers, manufactures, the quality assurance personnel and the regulatory body are the other participants in the commissioning activities.

5.1.1.5 Since construction, commissioning and operating activities overlap, the arrangement made in respect of manpower utilization between the construction, commissioning and operating groups shall ensure that the division of responsibilities remains clearly identified.

5.1.2 Commissioning Group

5.1.2.1 The commissioning group shall be headed by a commissioning group leader who shall have adequate experience with testing, commissioning and operation of nuclear power plants. He shall be appointed well in advance of the actual commissioning work so that he can make the necessary arrangements for scheduling and organising his work units, work plans and other resources.

5.1.2.2 The commissioning group leader shall prepare sub-organization charts showing the allocation of manpower and system responsibilities to each test team leader. The chart should be made available to other groups to ensure effective work coordination.

5.1.2.3 All sections in the commissioning group should maintain daily records of their commissioning activities and they should issue weekly/monthly progress reports.

5.1.2.4 There should be a planning and scheduling unit in the commissioning group to monitor and report the progress of commissioning in all its aspects, including the issuance of commissioning reports and transfer certificates of systems.

## 5.2 Responsibilities of the Responsible Organisation and Other Participants

5.2.1 Responsible Organization

5.2.1.1 The responsibilities of the responsible organization shall include the following:

1. To review, co-ordinate and control as applicable the activities of the construction, commissioning and operating groups in an effective manner ;

2. To ensure that the commissioning procedures are developed, reviewed and approved by personnel with appropriate technical background and experience ;

3. To arrange for the required submissions to the regulatory body at the agreed stages, and to comply with its requirements ;

4. To establish the procedures for ensuring co- ordination, taking account of the views and experience of members of the construction, commissioning and operating groups as well as other participants such as those from the designers, the manufacturers, the consultants and quality assurance personnel ;

5. To ensure the maintenance of adequate numbers of properly trained, experienced, qualified and, where required, authorized personnel in the construction, commissioning and operating groups ; and

6. To receive and disseminate information from and requirements of the regulatory body.

5.2.1.2 The essential tasks in achieving the necessary co- ordination are as follows:

1. To review the commissioning programme and have it issued after approval ;

2. To co-ordinate the provision and allocation of the manpower, materials and equipment required for commissioning ;

3. To identify and monitor the transfer of responsibilities from construction to commissioning to operation ;

4. To monitor the implementation of the commissioning programme ;

5. To resolve inter group and interface problems ;

6. To review test procedures and arrange for their approval and issue ;

7. To ensure compliance with safety aspects of proposed changes ;

8. To review test and phase completion ; and

9. To maintain liaison with the regulatory body ;

5.2.2 Construction Group (see Figs. 2A, 2B & 2C)

5.2.2.1 The responsibilities of construction group relevant to commissioning process shall be as follows:

1. To ensure that the installation of structures, systems and components has been completed in accordance with design requirements and specifications ;

2. To make suitable arrangements for surveillance and maintenance to prevent deterioration after the completion of installation ;

3. To issue installation completion certificates giving the necessary assurances to the commissioning group ;

4. To provide, for use as base-line data, as-built installation documentation and test certificates for tests done during manufacturing as well as installation periods including site tests such as air holding and hydrostatic tests highlighting design changes and concessions ;

5. To transfer the installed systems to the commissioning group using a system of documents such as transfer certificates ; and

6. To give necessary support to commissioning group by correcting installation deficiencies detected during commissioning ;

5.2.3 Commissioning Group

5.2.3.1 The commissioning group reports to the plant management under construction group till commencement of phase A commissioning. From phase A commissioning, they report to operating organisation (see Fig. 2A, 2B & 2C). The responsibilities of the commissioning group shall be as follows:

1. To plan in advance commissioning programmes with detailed test sequences, time schedules and manpower requirements ;

2. To review the commissioning programme in the light of commissioning experience ;

3. To ensure that operational flow sheets, operating and maintenance instructions, commissioning procedures, formats for commissioning and test reports, transfer documents, and submissions to the regulatory body are available ;

4. To verify that the installation of structures, systems and components has been satisfactorily completed and codified for proper identification ;

5. To establish and implement procedures that ensure orderly transfer of responsibility from the construction to the commissioning group for structures, systems and components ;

6. To ensure that an opportunity for systematic participation is provided for operating personnel to gain plant experience; typically this is done by utilizing the appropriate manpower, as required, for commissioning activities ;

7. To ensure that the prerequisites for the commissioning programme are satisfied, and that pre-operational tests such as functional, logic, interlock and system integrity checks are completed ;

8. To ensure that the systems are commissioned to meet their design intent and to confirm that the written operating procedures are adequate, for the intended modes of commissioning and operation ;

9. To ensure that the commissioning procedures comply with the appropriate radiological safety rules and relevant provisions of technical specifications ;

10. To direct the operation of systems within the commissioning programme and update operational flow sheets, operating and maintenance instructions, and procedures based on commissioning experience ;

11. To implement all tests in the commissioning programme ;

12. To make suitable arrangements for testing and maintaining systems (particularly safety-related items) for which responsibility has been accepted ;

13. To ensure that plant performance is within the technical specifications and in accordance with the design intent, including all aspects of radiological protection ;

14. To certify that the commissioning programme has been satisfactorily completed;

15. To transfer the commissioned systems and/or plant to the operating group, using a system of documents such as transfer certificates ;

16. To issue commissioning reports on tests ;

17. To issue test certificates and stage completion certificates ;

18. To provide up-to-date baseline information to the operating group and the operating organization ; and

19. To report to the operating organization any deficiency detected during commissioning tests in order to allow corrective actions to be taken.

5.2.4 Operating Group (see Fig. 2A, 2B & 2C) (Plant Management)

5.2.4.1 The responsibilities of the operating group relevant to commissioning shall be as follows:

1. To satisfy itself that the systems transferred comply with specified performance, design intent and safety requirements ;

2. To accept responsibility for the transferred systems ;

3. To participate in the commissioning activities ;

4. To become competent in the methods of operation of the plant ; and

5. To carry out operation and maintenance with competent staff, using approved procedures.

5.2.5 Other Participants in the Commissioning Activities

5.2.5.1 Among the responsibilities of other participants such as designers and manufacturers in the commissioning activities should be:

1. To co-operate with the commissioning group by active participation when required ;

2. To provide specialist knowledge and expertise and related experience from plants already commissioned ;

3. To provide base-line data and all necessary information ;

4. To provide independent safety assessment when necessary ; and

5. To incorporate engineering changes done in one standardised unit in other units under design construction or operation as applicable.

**5.3 Audits**

5.3.1 The responsible organization shall arrange for an audit to verify compliance of commissioning programme in a timely manner by a periodic review of all documents and records. The audit shall be performed by an appropriate team of experienced personnel not having direct responsibilities in the areas being audited.

5.3.2 The responsible organization shall take necessary action to correct in a timely manner any deficiencies revealed by the audit.

## 6. INTERFACES BETWEEN CONSTRUCTION, COMMISSIONING AND OPERATING ACTIVITIES AT THE SITE

### 6.1 Interface between Construction & Commissioning Activities

6.1.1 The following includes particular areas as appropriate to the construction-commissioning interface:-

1. Procedures for transferring structures, systems and components for commissioning ;

2. Pre-requisites for the start of the commissioning programme ;

3. Methods of identifying special technical, operational or manpower restrictions necessary as a result of partial completion of construction activity. Special precautions necessary for the commissioning of partly installed systems ;

4. Sequence of transfer of structures, systems and components consistent with commissioning priorities ;

5. Continual review of the as-built data with regard to any possible impact on commissioning ; and

6. Return of systems for rectification of defects arising out of commissioning tests.

### 6.2 Interface between Commissioning and Operating Activities at the Site

6.2.1 The following includes those areas that are appropriate for the commissioning-operations interface :

1. Procedures for transferring structures, systems and components for operation ;

2. Methods of identifying special technical, operational or manpower restrictions necessary as a result of partial completion of a commissioning activity ;

3. Baseline data derived from commissioning, e.g. the issuance of formal test reports and a statement of the existing radiological conditions ;

4. Changes in responsibility for safety reviews; implementation of modifications to the plant and to operating techniques; and nomination of responsible persons ;

5. Availability of design manuals, operating manuals, flow sheets and maintenance instructions and procedures ;

6. Conditions for access of personnel, taking into account delineation between systems already operating and those being tested ;

7. Withdrawal of procedures and equipment available during commissioning but not appropriate to normal operation, e.g. withdrawal of special start-up instrumentation after ensuring adequacy of normal plant instrumentation, withdrawal of duplicate safety keys, cancellation of authorization for the use of jumpers and override ;

8. Provision for the implementation of operating and maintenance requirements for structures, systems and components as each system is transferred to the operating group in the progress of the commissioning stage ;

9. Provision of sufficient opportunity to allow the operating personnel to become both trained and familiar with the operating/maintenance techniques of the plant ;

10. Radiological monitoring and protection procedures for site personnel ;

11. Reassessment of routine operating and maintenance instructions and procedures as a result of commissioning experience gained ;

12. Development of arrangements and instructions for emergency preparedness ; and

13. Establishment of adequate access control procedures and security arrangements.

# 7. DEVIATIONS DURING COMMISSIONING

## 7.1 General

During commissioning, changes to design, programmes or tests may be necessary, to cope up with unusual occurrences and/or unexpected results. The operating organisation should ensure that procedures are provided to deal with these situations.

## 7.2 Proposed Changes

Methods shall be developed to ensure that proposals for changes take into account the following :

(i) The Operating Organisation and Regulatory Body requirements:

In particular, changes to plant components and systems where safety is involved should be carried out as per written approved procedures (refer AERB/SC/O, section 15.4). These procedures shall cover design, safety assessment, and methodology of implementation and testing.

(ii) The safety implications arising from changes to the commissioning programme or to the individual test

The programme or test may then require the issue of new procedures or the revision of previously issued documents ; and

(iii) The effects of the proposed changes in any other systems

## 7.3 Unexpected Test Results & Occurrences

7.3.1 Despite adherence to good design, construction and commissioning procedures and good methods of working, unexpected test results or occurrences may arise during commissioning. To ensure that adequate consideration is given to such events, the following procedure shall be adopted :

(1) Commissioning documents shall contain as applicable instructions laying down specific and timely actions to be taken in the event of test results falling outside the specified limits ;

(2) A review shall be carried out to decide on the corrective actions to be taken.

## 7.4 Emergency Response to Accidents during Commissioning

7.4.1 The responsible organization shall ensure the preparation of instructions and procedures giving guidance on the action to be taken in the event of an accident or emergency for on-site and off-site response as mentioned in the Code of Practice for operation of nuclear power plants AERB/SC/O.

## 8. DOCUMENTATION

**8.1** Commissioning documents include those required to describe the proposed commissioning activities, to provide results and their evaluation, and to ensure that these activities have been correctly performed.

Other related documents are those needed to aid to the development of commissioning documents as pre- requisites for commissioning, as well as those operational documents needed to be verified during commissioning.

**8.2** Commissioning documents are normally provided by the commissioning group. They should:

1) Specify the action necessary for the execution and evaluation of testing ;

2) Enable commissioning to proceed safely and efficiently in accordance with specification ;

3) Permit the identification and transfer of plant and systems between the various groups ;

4) Collect base-line data for future reference ; and

5) Enable the integration of the many and various documents relating to the commissioning activity into a coherent pattern.

**8.3** Commissioning documentation arrangements should provide:

1) Continuity in the commissioning activity and a means for continuous updating of documents to facilitate the execution of stage reviews ;

2) Evidence to the various participants that the design intent has been met or appropriate modifications implemented ;

3) Assurance to the operating organisation that commissioning is proceeding in accordance with all stated requirements ;

4) Documentation in accordance with the quality assurance requirements ;

5) Records that are needed to be available throughout the life of the plant ;

6) Assurance to the regulatory body that its requirements are being satisfied.

**8.4** The commissioning group shall ensure that methods of approval, safe-keeping, retrieval and review of documents are specified. To facilitate document control, an integrated and consistent referencing procedure should be established covering all commissioning documents, and special methods of identification of important documents should be considered with self-checking features to facilitate reviews and audits of records. Document control procedures shall ensure that those participating in a commissioning activity are provided with approved procedures.

**8.5** Relevant commissioning documentation should include the following:

1) Commissioning schedules, procedures and reports :

   Commissioning programme and schedules, test procedures, data collection sheets, installation and completion certificates, standard test sheets, summary test reports, records of deficiencies noticed during commissioning and corrective actions taken, final test reports, test completion certificates, system transfer certificates, stage completion certificates ;

2) Documents providing baseline data and additional information for commissioning:

   Vendor specification, design and safety reports and subsequent changes thereof, regulatory body requirements, licenses and other applicable statutory documents ;

3) Documents to be verified during commissioning:

   Operational limits and conditions, operating and maintenance instructions and procedures, and other documents prepared for operation ;

4) Other documents relevant to commissioning:

   Record Systems for fuel and other nuclear materials, procedures for safety of personnel, radiological protection procedures and associated records ; and

5) All documents shall be signed by the persons involved in the commissioning tests and shall be vetted by the supervising engineers for analysing the results and ertifying approval ;

## APPENDIX-A

## INFORMATION TO BE INCLUDED IN THE APPLICATION FOR AUTHORISATION FOR HOT CONDITIONING OF PHT SYSTEM

### A.1 General

Hot conditioning of the PHT system is done to obtain a corrosion resistant adherent coating of magnetite on the internal surface of the carbon steel piping. During hot conditioning, the PHT system is subjected to full pressure and temperature for the first time. Approval of the Regulatory Body shall be obtained prior to hot conditioning.

### A.2 Submissions to be made along with theapplication for authorisation for hot conditioning shall include the following:

1. Proof of test of primary containment structure ;

2. Reactor Building leak rate test results ;

3. Overall commissioning activities chart, till the plant is declared commercial ;

4. Status of commissioning activities as on date ;

5. Report on availability of trained manpower at station ;

6. Preventive maintenance programme ;

7. Adequacy of availability of spares ;

8. Status of operating documents:

    a) System drawings,
    b) Operating manuals,
    c) Flow charts,
    d) System transfer documents,
    e) Technical Specifications for operation,
    f) Maintenance manuals,
    g) Training manuals,
    h) Commissioning procedures,
    i) Commissioning reports,
    j) Operating memos,

9. Submission of safety documents and safety reports; and

10. Submission of commissioning procedure containing information on:

a) Pre-requisites : A certificate from the station that all pre-requisites for various systems as given below for starting hot conditioning have been carried out successfully and the results obtained meet design intent.

   i) Boiler steam and feed water system : Mention all pre-requisites and the present status of the system,

   ii) Moderator System : Same as (i),

   iii) Ventilation System : Same as (i),

   iv) Suppression pool system : Same as (i),

   v) Reactor Auxiliary system : Same as (i),

   vi) Common services (PW system, standby and fire fighting system, compressed air system, electrical systems, general items)

   vii) Technical status of core components as installed including coolant channel. Also the actual garter spring locations just prior to filling of light water in,

b) Stepwise procedures for hot conditioning.

c) Observations, data collection, tests to be conducted etc. to be highlighted.

## APPENDIX-B

## INFORMATION TO BE INCLUDED IN THE APPLICATION FOR AUTHORISATION FOR FUEL LOADING AND HEAVY WATER ADDITION

### B.1 General

The first loading of the reactor core with fuel and filling heavy water are significant events as the configuration is potentially ready for reactor operation. Depending on the design features of the reactor the sequence of the activities for core fuel loading and heavy water addition may be required to be changed. The application for obtaining approval from regulatory authority for this activity should appropriately address this issue and the reason for the same with the required technical analysis.

The applications to Regulatory Body for these activities should include status on the necessary pre-requisites. A suggested list of such pre-requisites and other test conditions are given in this Appendix. It should be checked that all related reactor systems e.g. primary heat transport, ventilation, control and protection, containment, common services etc. are healthy and operational and all measures engineered and/or administrative to prevent inadvertent criticality have been identified and implemented before taking up the second of the activities of fuel and heavy water loading.

### B.2 Pre-requisites

#### B.2.1 General

1. System transfer from construction to commissioning/operation ;

2. Light water commissioning of moderator and primary heat transport systems and Emergency Core Cooling System (ECCS);

3. Hot conditioning of PHT along with the following :

   - report on actual garter spring location after draining and drying and the analysis if the garter springs are displaced from their original position to evaluate if the garter spring locations need to be readjusted as compared to base line data,

   - report on channel parameters, like straightness, bow, roughness, internal data etc. at selected locations in selected sample channels to be used as base line data for ISI,

4. Summary of phase A commissioning tests completed and the present status of deficiencies. (Check whether draining of light water is permissible with those deficiencies);

5. Draining of light water and drying, purging;

6. Status on operation and safety documents; and

7. Status on pending ECNs.

**B.2.2 Following Items should be covered in fuel loading procedure**

1. Pattern of fuel loading;

2. Procedure for identification and correct loading of natural/depleted uranium or thorium fuel bundles;

3. Precautionsfor Initial Fuel loading and documentation maintained; and

4. Status of Fuel Handling and Transport System.

**B.2.3 Pre-requisites for heavy water addition**

1. Vault ventilation and pump room ventilation;

2. Heavy water leak detection, collection, addition and transfer systems;

3. Calandria level indications for both wide range and narrow range available in control room. A manometer tube installed to confirm the actual moderator level as indicated in control room; and

4. Cover Gas system, moderator purification system, resin transfer system, deutration, de-deutration system.

**B.2.4 Pre-requisites for the later event fuel loading/heavy water addition to cover status on the following**

1. Regulating system including absorber rods, shimrods, adjuster rods;

2. Operability of protective system including primary/SDS1 and secondary shutdown systems/SDS2 and poison addition system (ALPAS & LPIS);

3. Operability of high pressure and low pressure ECCS;

4. Start-up instrumentation;

5. Core-neutron-flux-monitoring Ion chambers their source checking and end connection to trip circuits;

6. Filling of suppression pool to the required level and keeping suppression pool poised;

7. Containment system including Engineered Safety Features namely, containment isolation, containment post-accident heat removal and depressurisation system, filtration and pump-back system, secondary containment purge and recirculation system, etc.;

8. Establishing the operating island;

9. Radiological zoning establishment;

10. Commissioning report on preceding event initial fuel loading/D2O addition;

11. Status on pending items and review of earlier decisions; and

12. Status on establishing the reference base-line data for axial creep measurements with fuelling machine.

**B.2.5 The following activities and checks shall be completed before start of heavy water addition/fuel loading whichever is later**

1. Primary shutdown system/SDS1 has been tested. This system is in tripped condition and power supply to clutches is switched off if D2O filling is later activity;

2. Secondary shutdown system/SDS2 has been tested and is in poised state;

3. Moderator purification system valved out;

4. Start up counters are in position with trip settings at 1000 CPS. Ion chambers, checked with source and operating with linear neutron trip setting at 1% full power or lower. Log rate trip is set at 4% per sec. (These are connected to secondary shut down systems if D2O filling is after fuel loading);

5. Reactor Building leak-rate test completed;

6. Reactor Building and Service Building Ventilation system is in operation;

7. Auxiliary Systems i.e. Compressed Air (Instrument and Service air), chilled water, process water, fire fighting and vapour recovery dryers are operational;

8. Electrical System - Class I, Class II, Class III and Class IV power-supply is commissioned. Diesel generators and motor generator sets/static inverters are operable;

9. Fuel handling system is satisfactory and on-site trials are performed using dummy fuel;

10. Status of protection systems & associated logics mode, alarms and radiation protection equipments is verified to be as prescribed;

11. Radiation monitors, nuclear instrumentation, manual and automatic devices for actuating building isolation, ventilation control are tested and verified to be operable; and

12. Licensed personnel are available as per technical specifications requirements before taking up the later of two activities (Commencement of operation).

### B.2.6 Test conditions and procedures

The following items be considered for inclusion in the heavy water addition test conditions and procedures

1. Helium leak test;

2. Moderator system should be flushed with heavy water and circulated and sampled for isotopic purity, pH and conductivity;

3. Valve operations to be carried out as per written procedure for transfer of heavy water to the moderator system;

4. Maintenance of adequate information on the heavy water inventory in the moderator system; and

5. If D2O addition is taken up later, limits on Reactor vessel level increase and determination of frequency of boron concentration should be specified based on considerations of reactivity addition rate with level increase and worst possible dilution through piping system attached to moderator coolant system. While adding D2O in stages to the moderator system ensure specified boron concentration is maintained as per procedure.

## ANNEXURE-I

## DETAILED LIST OF COMMISSIONING TESTS FOR PRESSURISED HEAVY WATER REACTORS

### I.1 Introduction

I.1.1 This annexure provides detailed list of tests to be given consideration in the development of a commissioning programme. The list of tests is not to be considered complete, since the test requirements of a specific design or type of PHWR may vary and may require additional or different tests.

I.1.2 Testing is to be sufficiently comprehensive to establish that the plant can operate in all modes for which it has been designed to operate. However, tests are not to be conducted for operating modes or plant configurations outside the range of assumptions used in analysing postulated accidents in the safety report.

I.1.3 The following points have to be carefully considered in determining the sequence of testing:

(1) The need for prior testing of certain systems so that they are available for the proper testing of other systems;

(2) The need for certain systems to be operational to ensure that other systems can be tested without jeopardizing safety.

### I.2 Pre-requisites for phase A

#### I.2.1 General

Before the initial testing of any structure, system or component, the following points need to be considered:

(1) Completion and documentation of construction activities associated with the system;

(2) Provision of assurance that the equipment is ready for operation, e.g. inspection for proper fabrication (including welding) and cleanliness, check-out of electrical and protective devices, adjustment of settings on valve position limit switches, torque-limiting devices, calibration of instruments, verification of operability of instrument loops and required response times, adjustment and settings of process controllers and limit switches;

(3) Provision of assurance that test equipment is operable and properly calibrated and that response times are as required;

(4) Checks to assure physical separation of safety system equipment and associated power/control cables, air lines, signal lines, etc. as stipulated in design.

### I.2.2 Functional Tests of Individual Sub-Systems or Components

Typical tests to be considered are as follows:

(Note that some items are applicable only to important or special components, and some tests may be included in phase A itself).

(1) Valves: Leakage, opening and closing times, valve stroke, position indication, torque and travel limiting settings, operability against pressure, correct settings and functioning of relief and safety valves;

(2) Motors and generators: Direction of rotation, vibration, overload and short circuit protection, margins between set points and full load running current, lubrication, neutral grounding, insulation tests, supply voltage, phase-to-phase checks, neutral current, acceleration under load, temperature rise under specified cold and hot starting conditions, phase currents, load limiting capability for both time and load (generators);

(3) Pumps, and Fans: Vibration, motor load versus time, seal or gland leakage, seal cooling, flow and pressure characteristics, lubrication, acceleration and coast down;

(4) Piping and Vessels: Pressure tests, leak tightness, cleaning and flushing, clearance of obstructions, support adjustments, proper gasketing, bolt torque, insulation, filling, draining, venting & over pressure relief, hot and cold set points of spring loaded hangers to be recorded;

(5) Instrumentation and Control: Voltage, frequency, current, circuit breaker operation, bus-bar transfers, trip settings, operation of prohibit and permissive inter-locks, calibration, logic and loop checking; and

(6) Pre-Service Inspection: This is done to provide baseline data such as feeder pipe and header inspection, garter spring locations, coolant channel gap measurement for subsequent creep adjustment/boiler hanger rod support spring positions. This is covered in detail in AERB/SG/O-2.

## I.3 Phase A: Pre-Operational Commissioning Tests

### I.3.1 General

I.3.1.1 A satisfactory pre-operational commissioning test programme takes account of the proper sequence of tests. The initial part of this programme consists of test

on electrical systems, instrumentation systems, and other service systems such as cooling water, compressed air system and fire water systems to ensure availability of the necessary services for the implementation of rest of the programme.

I.3.1.2 Specific mention of the applicability of cold and hot performance testing for individual systems has not been made in the list of tests given in this Annexure. The need for performing cold and hot performance tests has to be considered carefully during appropriate phase of commissioning.

I.3.1.3 In some cases, shop and construction tests already conducted may not need to be repeated at this stage. In such cases, before these tests are accepted as fulfilling pre-operational test requirements, due consideration is to be given to the shop test conditions.

I.3.1.4 A representative list of tests to be considered for structures, systems and components included in this Phase is given in sub-sections I.3.2 - I.3.15.

## I.3.2 Primary Heat Transport System

The primary heat transport (PHT) system includes the main circulating system, shut down cooling system, emergency core cooling system, purification system, fuelling machine supply system, leakage collection system together with such items as the associated tanks, pumps, valves and instrumentation. Following tests are included for commissioning PHT system :

(1) Pressure boundary integrity test ;

(2) Base Line Data for ISI ;

(3) Component Tests: Appropriate tests on PHT system components, including :

(i) Pressurizer,

(ii) Pumps, with associated motors, gland cooling, oil supply unit etc.,

(iii) Steam Generators and other heat exchangers,

(iv) Pressure relief valves (with associated tanks and cooling circuits) and supports and restraints for discharge,

(v) Control valves,

(vi) Valves, strainers/filters, IX columns, tanks etc.,

(vii) Instrumentation used for monitoring system performance and logic functions,

(viii) ECCS : Operation, coolant make-up & accident conditions,

(ix) Cover Gas System,

(x) Heavy water addition & transfer system,

(4) System Tests: Expansion and restraint tests to confirm acceptability of clearances and displacements of tanks, Heat exchangers, piping, piping hangers, hold-down support, or restraining devices such as for seismic protection in the as- built system; hot performance and/or cold testing of the system with simultaneous operation of auxiliary systems including chemical control aspects;

(5) Vibration Tests: Vibration monitoring of reactor internals and other components such as piping systems, heat exchangers, steam generators and rotating machinery;

### I.3.3 Moderator System

Tests on the moderator system include:

(1) Component tests : appropriate tests of system components, including:

(i) Pumps and motors,

(ii) Cover gas circulators (blowers),

(iii) Cover gas re-combination units,

(iv) Relief valves in cover gas system,

(v) Purification IX columns,

(vi) Liquid poison, addition system tanks and valves and ejectors,

(vii) Moderator leakage collection system including floor beetles and vacuum mopping system,

(viii) Heavy water addition & Transfer system,

(2) System Tests: Cold performance test of system, including cover gas system and auxiliary systems for chemical control, level monitoring instrumentation and logics;

(3) Vibration tests of pumps and piping inside and outside vaults.

### I.3.4 Reactivity Control Systems

Tests on the reactor control systems include:

(1) Adjuster rods tests : Normal operation like speed, insert & withdrawal timings, flow adjustments, rod position instrumentation, logics and interlocks.Liquid zone control rods functional tests;

(2) Ion Chambers, count rate meters and In-core flux monitoring system calibration and sensitivity checks of Ion chambers by external source and its associated amplification circuit; and

(3) Liquid poison addition system tests operation of the systems with demineralised water, mixing of poison with moderator and adequacy of sampling system; operability of instrumentation, control, interlocks & alarms; operation of quick acting valves, redundancies & independence.

### I.3.5 Reactor Protection Systems

I.3.5.1 Tests on the reactor protection systems include response of protection channels including sensors and associated hardware, operation in all combinations of logic, calibration and operability of primary sensors, trip and alarm settings, operability in conjunction with other systems, redundancy, coincidence and Safe failure on loss of power, operability of any devices provided to protect the plant for anticipated operational occurrences (can be scheduled prior and closer to initial criticality).

I.3.5.2 Primary Shutdown System (PSS)/Shutdown System 1 (SDS1)

Rod operability tests including tests insertion timings, withdrawal timings and logic/interlocks including those related to SSS/SDS2, adjusters and ALPAS as applicable.

I.3.5.3 Secondary Shutdown System (SSS)/Shutdown System 2 (SDS2)

Operability tests, insertion timings, (withdrawal timings for SSS), logic checks/interlocks including in relation to PSS/SDS1, adjusters and ALPAS as applicable.

I.3.5.4 Automatic Poison Addition System (ALPAS)/Liquid Poison Addition System (LPIS)

Operation of the systems along with moderator, interlocks/logic, timing of operation, dispersion of poison (need not be phase A).

### I.3.6 Power Conversion System

The power conversion system includes all components provided to transfer the reactor thermal energy during normal operation from the reactor coolant system to the main condenser and those systems and components provided for return of condensate and feed water from the main condenser to complete the cycle. System expansion, restraint and operability tests are to be carried out, and other appropriate tests on the following components and systems:

(1) Steam generators;

(2) Steam and feed water process lines;

(3) Condensate and feed water system;
(4) Main condenser auxiliaries used for maintaining condenser vacuum;

(5) Auxiliary feed water system;

(6) Condensate make-up water system;

(7) Chemical treatment systems;

(8) Turbine stop, control, intercept valves;

(9) Steam dump, discharge and safety relief valves;

(10) Steam extraction system;

(11) Feed water heater, deaerators and drain systems;

(12) Main Condenser Auxiliaries used for maintaining condenser vacuum;

(13) Condenser cooling water system including natural drought cooling tower (NDCT) & plant water make-up;

(14) Turbo generator and its auxiliaries such as H2 cooling system, seal & oil system, etc;

(15) Hydrogen leak detection system;

(16) Turbine governing system;

(17) Turbovisory equipment; and

(18) Datum block readings.

### I.3.7 Reactor Auxiliary Systems

(1) Ventilation and heavy water vapour recovery system : This should include operability of fans, dampers, air coolers, vapour recovery dryers, control of temperature, associated instrumentation & control logic, air flows & flow balancing, leak tightness of clutch, etc;

(2) End shield cooling system : Flow adjustment, operability of pumps & valves, end shield venting, make-up system, chemical control system and associated instrumentation;

(3) Calandria vault cooling system : operability of pumps & valves, make-up system, chemical control and associated instrumentation; and

(4) Annulus gas monitoring system : Gas addition station, piping, valves & associated instrumentation.

### I.3.8 Common Services

(1) Compressed Air : This includes compressors, valves, heaters, receivers, filters, piping and instrumentation for instrument Air, Service Air and Mask air systems, as well as other compressed air systems used for safety related functions;

(2) Fire Protection system, including use of Fire Water system for back-up cooling : Pumps, piping, valves and instrumentation;

(3) Process Water System : including cooling tower, pumps, valves, strainers, pipes, instrumentation and flow balancing of closed loop circulation & miscellaneous equipment cooling system;

(4) Air Conditioning and Ventilation System : Fans, ducts, dampers, chiller units, piping, tanks and associated instrumentation and controls; and

(5) Communication System : PA System, telephone system, maintenance phone, wireless communication system equipment.

### I.3.9 Electrical systems

The plant electrical systems include normal A.C. power distribution, emergency A.C. power distribution system, emergency A.C. power supplies, D.C. supply and distribution system;

(1) Normal A.C. Power Distribution System : Operation of protection devices, initiating devices, relaying and logic, setting and calibration of all relays and their functional testing, breakers, motor control centers, switch gear, transformers, and

close trip devices, inhibit and permissive interlocks, instrumentation and alarms, integrated system performance on designed full load with simulated partial and total loss of off-site power under worst conditions, capability to transfer from on-site to off-site power sources and operation from local and from control room;

(2) Vital bus-bar and associated A.C. Power Supplies : Include a load test with full load and minimum sources of power supplies to bus-bars.

(3) D.C. system : Calibration and trip settings of protective devices, including relaying, operation of breakers, prohibit and permissive interlocks; capability of battery chargers, transfer devices, inverters, instrumentation and alarms used to monitor system availability, including under voltage, over voltage alarms and ground detection instrumentation, redundancy and electrical independence, total system loads discharge test of each battery bank at full plant load and for the specified duration, adequacy of emergency lighting;

(4) Emergency A.C. power distribution system : Includes operation of protection devices, relaying and logic, setting and calibration of relays, breaker, (operation in Auto/Manual, local and remote), motor control centres, switch gear, transformers, close and trip devices, inhibit and permissive interlocks, instrumentation and alarms, load-shedding capabilities, capability of safety related loads to start in the desired sequence, operate under simulated accident conditions with both the normal (preferred) A.C. power sources and/or emergency (standby) power source in accordance with design requirement for voltage and frequency; Load tests of diesel generators or equivalent machines, capability to start and operate with maximum and minimum design voltage available within specified time, testing of emergency loads for a sufficient period of time to provide assurance that equilibrium conditions are attained; system redundancy and electrical independence verified; loads supplied from the system such as UPS sets designed to provide non- interruptible power to vital plant loads tested to demonstrate proper operation; load tests for vital bus-bars using normal and emergency sources of power supplies to the bus-bar; operation of indicating and alarm devices used to monitor the availability of the emergency power system locally in the control room; adequacy of the plant's emergency lighting system. Integrated heat run test be carried out for electrical system with all control/logic system available. All systems should be tested till all parameters stabilize;

(5) Emergency or Standby A.C. Power supplies : Redundancy, electrical independence, manual/automatic starting, emergency transfer and proper voltage and frequency regulation under transient and steady-state conditions; performance of auxiliary systems, such as those used for starting, cooling, heating, ventilating, lubricating and fuelling, duration of test to ensure equilibrium conditions are attained; logic, setting and calibration of all relays and trip devices and proper operation of initiating devices inhibit and permissive interlocks, redundancy and electrical independence.

### I.3.10 Containment Systems

Following tests should be included :

(a) Primary containment proof test;

(b) Integrated containment leak rate tests for primary and secondary containments;

(c) Secondary containment vacuum test;

(d) Primary containment volume V-1/V-2 leak rate test;

(e) Functional tests on containment isolation valves, dampers,air locks and associated logic/instrumentation;

(f) Containment vapour pressure suppression system including suppression pool and its water circulation system along with associated instrumentation;

(g) Containment atmosphere clean-up system including purging and depressurisation; and

(h) Vacuum breaker testing.

### I.3.11 Radioactive Waste Disposal Systems

Equipment and instrumentation related to

(a) Active drainage system;

(b) Inactive draining system;

(c) Decontamination center;

(d) Liquid effluent segregation and storage system;

(e) Liquid effluent treatment and disposal;

(f) Solid waste handling fixation and storage facilities; and

(g) Sampling and surveillance systems.

### I.3.12 Fuel Handling, Transfer and Spent Fuel Storage

Tests are to demonstrate operability in accordance with the design intent of equipment and components used to handle or cool irradiated fuel and to handle non- irradiated fuel. These may include:

(1) Test and calibration of fuelling machines, drives (X, Y & Z), control & instrumentation systems and functional tests;

(2) Fuel transfer system : $D_2O$ systems, oil system, $H_2O$ system, valve stations, fuel transfer room equipment, roll on shields, air locks, F/M service area equipment, Spent fuel receiving, inspection and storage equipment and associated instrumentation and control;

(3) Spent fuel storage bay cooling and purification systems (including testing of antisiphon devices, high radiation alarms and low water level alarms);

(4) Tests on containment devices, leakage and ventilation in the fuel discharge route;

(5) Material Handling facilities in SFSB area;

(6) Spent fuel shifting flasks;

(7) Decontamination facilities in SFSB area; and

(8) Integrated testing of fuel handling and transfer system.

### I.3.13 Reactor Components systems

Tests on the components such as

(i) Garter springs location checking after hot conditioning;

(ii) Baseline data for creep measurement.

### I.3.14 Radiation Protection Systems

Tests on systems and components used to monitor radiation levels to provide for personnel protection or to control or limit the release of radioactivity include the following:

(1) Area radiation monitors (RADAS);

(2) Stack monitoring system;

(3) Tests on personnel monitors and radiation survey instruments;

(4) Tests on laboratory equipment used to analyse or measure radiation levels and radioactivity concentrations; and

(5) In-situ efficiency tests of high efficiency particulate air filters and absorption filters.

### I.3.15 Instrumentation and Control Systems and Main control centre:

Tests on the instrumentation and control systems cover control functions for normal operation, and instrumentation to provide alarms for off-normal conditions in order to initiate corrective action and to monitor sequence of events. Instrumentation and control systems need to be tested over the design operating range, and limiting malfunctions and failures tested by simulation. A typical list of instrumentation(some of this equipment may be tested in conjunction with the control system) covers the following:

(1) Bleed condenser pressure, temperature and level control, pressurizer pressure and level control;

(2) Feed water flow control;

(3) Steam generator, pressure and level control;

(4) PHT pressure control;

(5) PHT flow and temperature monitoring;

(6) Reactor regulation system;

(7) Reactor protection system;

(8) Seismic instrumentation;

(9) Failed fuel detection system;

(10) In-core flux monitoring and ion chambers instrumentation;

(11) Reactor start up instrumentation;

(12) Detection of external and internal flooding conditions;

(13) Annunciation system;

(14) Control operator information system, programmable digital comparator system, radiation data acquisition system, fuel handling control system etc;

(15) Sampling systems ($D_2O$, $H_2O$, FW, steam, air), gas chromatograph, $D_2O$ to $H_2O$ leak detection, stack loss monitor, on line activity monitors;

(16) Detection of external and internal flooding conditions; and

(17) Instrumentation monitoring the course of postulated accident conditions.

### I.3.16 Supplementary Control Room

Testing of all the features provided for independent protection, control and monitoring. Habitability checks, provision of procedures and documents required to handle emergencies.

### I.3.17 Engineered Safety Features

These systems have generally been covered as part of commissioning of main system. However, due to their importance in safety they are grouped again under this title :

(1) Emergency core cooling systems (ECCS) and essential auxiliary systems. Equipment, piping, instrumentation and control logics.

(2) Crash cooling system instrumentation logic.

(3) Containment post-accident heat-removal systems : Pump room and F/M vault coolers.

(4) Containment combustible gas control system.

(5) Interlocks, for operation of main and emergency air locks.

(6) Emergency Water supply system (use of fire water for steam generators & ECCS).

(7) Emergency feed water system (ABFP & ACEP).

(8) Emergency power supply system (DGs & UPSCs).

(9) Containment clean-up, purge and depressurisation system.

(10) Containment, isolation & pressure suppression system.

Commissioning of these systems should include : tests for satisfactory performance in all expected operating configurations or modes, operation of initiating devices, correct logic and set point, operation of bypasses, interlocks and equipment protective devices. Concurrent testing of support systems to ensure the operation of engineered safety features are also to be conducted using the minimum number of operable components available with which these systems are designed to function. These include systems and components such as heating, ventilation and air- conditioning systems, water and seal injection systems and compressed air supplies; functioning of protective devices, leak tight covers or housing provided to protect engineered safety features from flooding, keep systems full to prevent 'water hammer' and possible damage to fluid systems or affect the logic of operation of ESFs (ECCS).

## I.4 Phase B: Initial Criticality and Low Power Tests

### I.4.1 Tests before taking up initial criticality procedure

Before reactivity is inserted to approach initial criticality, the fuel loading and heavy water addition are to be completed along with the appropriate pre- requisites (See Appendix A) to ensure that the reactor is in proper condition for start up. The following list is illustrative of the types of tests and verifications that are to be conducted prior to initiating procedure for approach to first criticality.

(1) Reactivity control rod withdrawal and insert speeds, rod position indication, protective interlocks and circuitry, and scram timing of shut- off devices;

(2) All reactor trip logics on all protective channels are checked to be operative as per technical specifications and also for the special test required for initial criticality procedure;

(3) Operability of all computer systems in the control room;

(4) Operability of reactor coolant system and moderator system as required for criticality procedure and also their purification systems;

(5) Chemical Tests: water quality and boron concentration of the reactor coolant and/or moderator system; and

(6) Calibration and neutron response check of start up channels ; power range; verification of proper operation of associated alarms and protective functions.

### I.4.2 Low Power Tests (Reactor Power limited to 0.1% of FP)

I.4.2.1 After achieving initial criticality, tests are performed as needed to verify that characteristics of the core, reactivity control and shut down systems, reactivity co-efficient and shielding are as given in the safety report, and to confirm the operability of plant systems and design features that could not be completely tested during the pre-operational phase.

I.4.2.2 The following is an illustrative list of the tests to be conducted as applicable (additional special tests could be planned for verifying new design features of regulation/protection devices or for new fuel loading pattern etc.) :

(1) Transfer of reactor power regulation to outer control > 1.0E-5;

(2) Determination of neutron poison concentration at initial criticality. Comparison of actual critical Boron concentration for criticality;

(3) Determination that adequate overlap of start-up and power range neutron instrumentation exists and verification of alarms and protective functions intended for operation in the low power test range;

(4) Calibration/measurements of adjusters/zone control rods, reactivity worth of auto/manual poison addition system features;

(5) Reactor shut-down systems dynamic tests. Such tests may also be done on individual rods or their combinations under subcritical state;

(6) Coolant/moderator temperature reactivity coefficient measurement over the temperature range and poison concentration range in which the reactor may be made critical (need not be repeated for similar reactors);

(7) Neutron and gamma radiation surveys; and

(8) Flux distribution measurements with incore flux mapping provisions.

**I.5 Phase C: Power Tests: (0.1% Full Power to 100% Full Power).**

The following list is illustrative of the types of performance demonstration and tests in Phase C:

(1) Thermosyphoning tests of PHT systems (for new configurations of the system only);

(2) Dynamic plant response to the design load swings including step and ram changes, and response to automatic control;

(3) Chemical analysis (at frequent intervals);

(4) Functioning of chemical and radiochemical control systems and sampling to verify that reactor coolant system and secondary coolant system are within specified limits;

(5) Effluent Monitoring Systems : Verification of calibration by laboratory analysis of samples (as early in power ascension as possible and repeated at defined power steps);

(6) Process and effluent radiation monitoring systems : correctness of response;

(7) Evaluation of Core Performance : Reactor power measurements, verification and calibration of neutron power signal and boiler delta T values, flux tilt control, throughout the permissible range of power. Channel outlet temperature readings versus design power-flow expectations;

(8) Radiation surveys to determine shielding effectiveness;

(9) Control Room Computer Systems : Comparison of safety-related computer monitored values with measured values; verification of control room or process

computer inputs from process variables, data printouts, and validation of performance calculations performed by the computer; validation of all computer safety functions;

(10) Relief valve functional test : verification of operability, response times, set points, and reset pressures, as appropriate, for primary steam line relief valves;

(11) Verification of operability and response times of main steam line and branch steam line isolation valves;

(11) Evaluation of performance of shutdown cooling system, capability of all systems and components provided to remove residual or decay heat from the reactor coolant system, including condenser steam dump valves, residual heat removal system in steam condensing mode, auxiliary feedwater system; [testing of the auxiliary feedwater system to include provisions that will provide reasonable assurance that excessive flow instabilities (e.g. 'water hammer') will not occur during subsequent normal system startup and operation (before exceeding 25% power).];

(13) Verification of performance of major or principal plant control such as PHT pressure control, Boiler level control, turbine generator/speeder, condenser hot well level control; steam pressure control etc.;

(14) Dynamic response of the plant and subsequent steadystate of the plant for single and multiple reactor coolant pump trips;

(15) Feedwater Pump Trip-out and stand by pump restart;

(16) Operation of the reactor coolant system with the plant at steady-state conditions to establish performance of all heat removal systems at power e.g. PHT, moderator, reactor control, reactor auxiliaries, process water, IDCT, secondary system, NDCT and overall heat balance;

(17) Effectiveness of reactor coolant leak detection systems, if not previously demonstrated;

(18) Operation of failed fuel detection systems in accordance with predictions;

(19) End shield and Calandria vault cooling systems : Maintenance of temperatures with the minimum design capability of cooling available;

(20) Performance of the auxiliary systems for the operation of engineered safety features with the minimum design capability of operable components in these auxiliary systems;

(21) Operation of gaseous and liquid radioactive waste processing, storage and release systems;

(22) Dynamic response of the plant for a simulated condition of loss of turbine-generator coincident with loss of off-site power;

(23) Dynamic response of the plant to load rejections including turbine trip;

(24) Operability of the automatic closure of all main steam line isolation valves. The test may be made at a low power level to demonstrate proper plant response to this transient;

(25) Observations and measurements, as appropriate, to ensure that piping and component movements, vibrations and expansions are acceptable for safety systems. (Tests performed during low-power testing need not be repeated);

(26) Dynamic response of the core and plant to fast-load changes initiated by the load control;

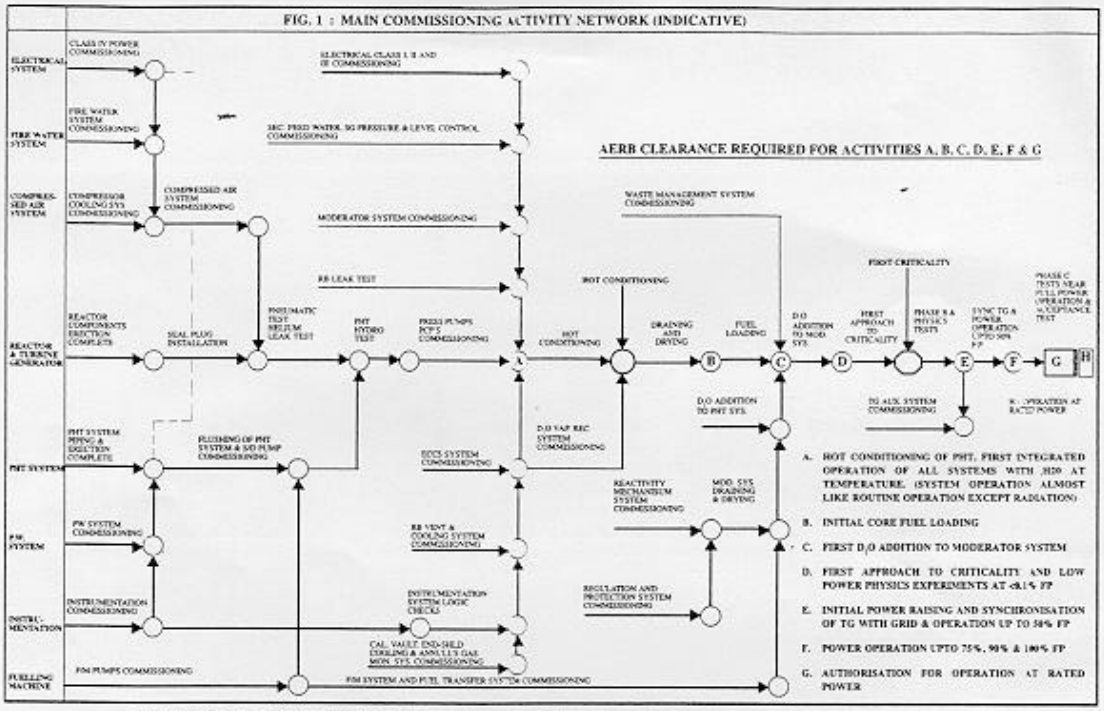
(27) Performance of ventilation and air conditioning systems;

(28) Shutdown from emergency control room;

(29) Operability of atmosphere steam discharge valves and steam relief valves at rated pressure; and

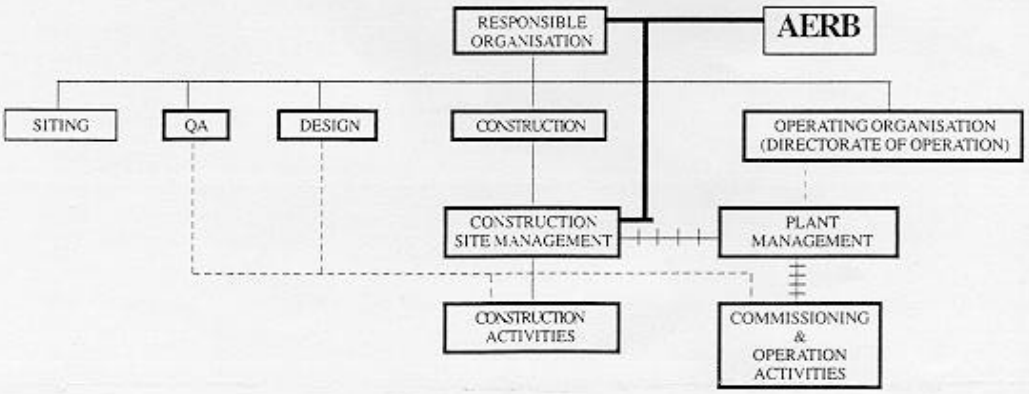
(30) Operability of residual or decay heat removal systems.

FIG. 1 : MAIN COMMISSIONING ACTIVITY NETWORK (INDICATIVE)




THE ABOVE IS A TYPICAL NETWORK COVERING MAJOR ACTIVITIES, DETAILED NETWORK TO BE SUBMITTED.
RO/OO/PM MAY SUBMIT ALTERNATIVE NETWORK FOR APPROVAL

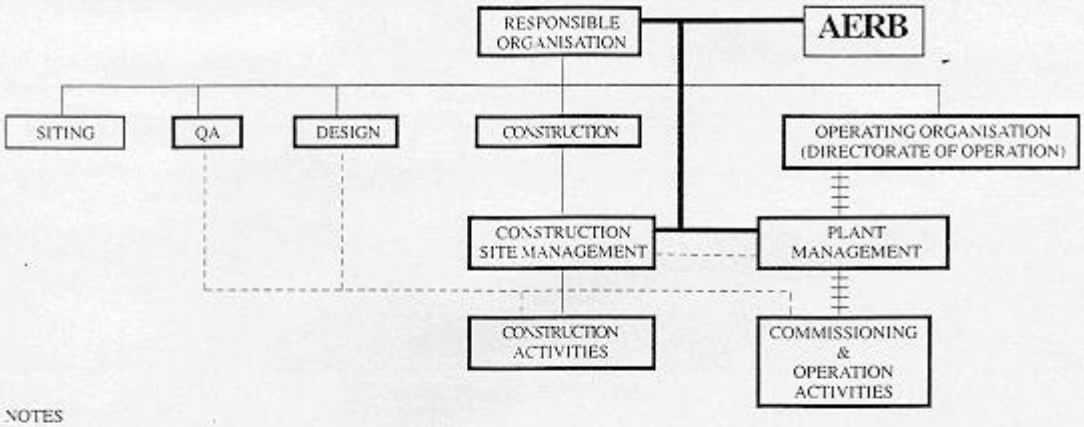
FIG. 2A: TYPICAL FUNCTIONAL ORGANISATION CHART DURING CONSTRUCTION PHASE AND PRIOR TO PHASE A COMMISSIONING




NOTES

1. INDICATES LINE OF COMMAND FOR COMMISSIONING AND OPERATION ACTIVITIES.
2. INDICATES LINE OF COMMAND FOR OTHER STATION RELATED ACTIVITIES.
3. INDICATES LINE OF COMMUNICATION.
4. INDICATES REGULATORY FUNCTIONAL RESPONSIBILITIES AND CONTROL.
5. DURING CONSTRUCTION, THE PLANT MANAGEMENT IS CONTROLLED, ADMINISTRATIVELY BY CONSTRUCTION SITE MANAGEMENT.
6. WHERE Op.O IS NOT DEFINED, THESE FUNCTIONS ARE THE RESPONSIBILITY OF RO OR PLANT MANAGEMENT AS

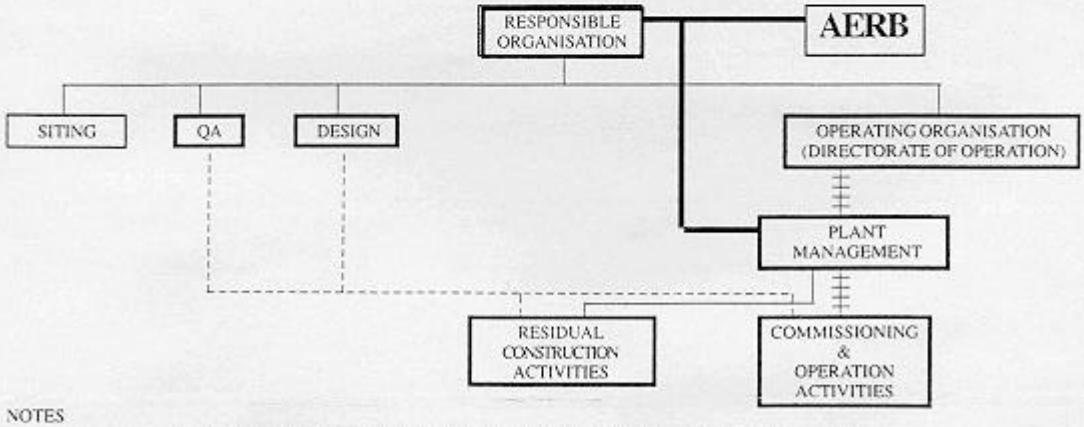
FIG. 2B: TYPICAL FUNCTIONAL ORGANISATION CHART FROM PHASE A COMMISSIONING ONWARDS THROUGH PHASE C COMMISSIONING AND POST COMMISSIONING




NOTES

1. —+—+—+— INDICATES LINE OF COMMAND FOR COMMISSIONING AND OPERATION ACTIVITIES.
2. ———— INDICATES LINE OF COMMAND FOR OTHER STATION RELATED ACTIVITIES.
3. - - - - - - - - - - INDICATES LINE OF COMMUNICATION.
4. ▬▬▬▬ INDICATES REGULATORY FUNCTIONAL RESPONSIBILITIES AND CONTROL.
5. FROM PHASE-A COMMISSIONING ONWARDS PLANT MANAGEMENT COMES UNDER OPERATING ORGANISATION. HOWEVER IF DECIDED BY RO, PLANT MANAGEMENT MAY BE UNDER CONSTRUCTION SITE MANAGEMENT FOR ADMINISTRATION PURPOSE ONLY TILL THE UNIT IS DECLARED COMMERCIAL.
6. WHERE Op.O IS NOT DEFINED, THESE FUNCTIONS ARE THE RESPONSIBILITY OF RO OR PLANT MANAGEMENT AS DELEGATED BY RO.

FIG. 2C: TYPICAL FUNCTIONAL ORGANISATION CHART DURING EARLY OPERATION OF A MULTI UNIT STATION




NOTES

1. —+—+—+— INDICATES LINE OF COMMAND FOR COMMISSIONING AND OPERATION ACTIVITIES.
2. ———— INDICATES LINE OF COMMAND FOR OTHER STATION RELATED ACTIVITIES.
3. - - - - - - - - - - INDICATES LINE OF COMMUNICATION.
4. ▬▬▬▬ INDICATES REGULATORY FUNCTIONAL RESPONSIBILITIES AND CONTROL.
5. IN A MULTI UNIT STATION, WHILE SOME UNIT(S) WILL BE OPERATIONAL, THE OTHER UNIT(S) MAY BE UNDER CONSTRUCTION PRIOR TO COMMISSIONING. ONCE THE COMMISSIONING ACTIVITIES OF THE LAST UNIT ARE TAKEN-UP BY THE PLANT MANAGEMENT, THE RESIDUAL CONSTRUCTION SITE MANAGEMENT COMES UNDER PLANT MANAGEMENT.
6. WHERE Op.O IS NOT DEFINED, THESE FUNCTIONS ARE THE RESPONSIBILITY OF RO OR PLANT MANAGEMENT AS

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# LIST OF PARTICIPANTS

**8520/Advisory Committee on Codes, Guides & Associated Manuals for Safety in Operation of Nuclear Power Plants (ACCGASO)**

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| Dates of Meeting | : | January 14, 15 & 17, 1993<br>March 17, 1993<br>June 16 & 17, 1993<br>July 21 & 22, 1993<br>August 18, 19 & 20, 1993<br>January 31 & February 1, 1997. |

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