GUIDELINES NO. AERB/HWP/SG-2

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GOVERNMENT OF INDIA

AERB SAFETY GUIDELINES

LIFE MANAGEMENT OF HEAVY WATER PLANTS

ATOMIC ENERGY REGULATORY BOARD

AERB SAFETY GUIDELINES NO. AERB/HWP/SG-2

LIFE MANAGEMENT
OF
HEAVY WATER PLANTS

Atomic Energy Regulatory Board
Mumbai-400 094
India

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Price:

Order for this Guidelines should be addressed to:

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Atomic Energy Regulatory Board
Niyamak Bhavan
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FOREWORD

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

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

It is known that structures, systems and components of heavy water plant are likely to undergo wear and degradation with age. The potential degradation mechanisms include corrosion, erosion, creep and a combination of these factors. This ‘guidelines’ addresses the requirements and guidance on the issues related to such causative factors, timely detection of incipient failures and preventive/mitigation measures. A programme for life management should be instituted for each HWP so as to ensure that, items important to safety of the HWP function without impairment of their reliability and intended safety margins. While drafting this guide document, extensive use has been made of the information contained in the relevant documents of AERB and IAEA on life management of nuclear power plants. This ‘guidelines’ applies to all the existing and future heavy water plants.

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

For aspects not covered in this ‘guidelines’, applicable national and international standards, codes and guides acceptable to AERB should be followed. Non-radiological aspects such as industrial safety and environmental protection are not explicitly considered in this ‘guidelines’. Industrial safety is to be ensured through compliance with the applicable provisions of the Factories Act, 1948 and the Atomic Energy (Factories) Rules, 1996 and the environmental safety through provisions of the Environmental Protection Act, 1986.

This ‘guidelines’ has been prepared by specialists in the field drawn from Atomic Energy Regulatory Board, Bhabha Atomic Research Centre, Nuclear Power Corporation of India Ltd., and Heavy Water Board. It has been reviewed by the ‘Advisory Committee on Safety Documents relating to Fuel Cycle Facilities other than Nuclear Reactors’ (ACSD-FCF).

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

(S. S. Bajaj)
Chairman, AERB

DEFINITIONS

Active Component

A component whose functioning depends on an external input, such as actuation, mechanical movement, or supply of power and which therefore influences the system process in an active manner eg. pumps, valves, fans, relays and transistors. It is emphasized that this definition is necessarily general in nature, as is the corresponding definition of passive component. Certain components, such as rupture discs, check valves, injectors and some solid state electronic devices, have characteristics which require special consideration before designation as an active or passive component.

Ageing

General process in which characteristics of structures, systems or component gradually change with time or use.

Atomic Energy Regulatory Board (AERB)

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

Consent

A written permission issued to the 'consentee' by the regulatory body to perform specified activities related to nuclear and radiation facilities. The types of consents are 'licence', 'authorisation', 'registration' and 'approval', and will apply according to the category of the facility, the particular activity and radiation source involved.

Design Life

The period for which the item will perform satisfactorily meeting the criteria set forth in the design specification.

In-service Inspection (ISI)

Inspections of structures, systems and components carried out at stipulated intervals during the service life of the plant.

Inspection

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

Licence

A type of regulatory consent, granted by the regulatory body for all sources, practices and uses for nuclear facilities involving the nuclear fuel cycle and also certain categories of radiation facilities. It also means authority given by the regulatory body to a person to operate the above said facilities.

Passive Component

A component which has no moving part and only experiences a change in process parameters such as pressure, temperature, or fluid flow in performing its functions. In addition, certain components, which function with very high reliability, based on irreversible action or change, may be assigned to this category (examples of passive components are heat exchangers, pipes, vessels, electrical cables and structures. Certain components such as rupture discs, check valves, injectors and some solid state electronic devices have characteristics, which require special consideration before designation as an active or passive component).

Predictive Maintenance

It is a form of preventive maintenance performed continuously or at intervals governed by observed condition to monitor, diagnose or trend a structure, system or component's condition indicators; results indicate current and future functional ability or the nature of and schedule for planned maintenance. It is also known as condition based maintenance.

Pre-operational Stage

The stage of study and investigation after the start of construction and before the start of operation in order to complete and refine the assessment of site/plant data characteristics.

Preventive Maintenance

Maintenance carried out at pre-determined intervals or according to prescribed criteria and to reduce the probability of failure or the degradation of the functioning of an entity.

Regulatory Body

See 'Atomic Energy Regulatory Board'.

Responsible Organisation

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

Risk

A multi-attribute quantity expressing hazard, danger or chance of harmful or injurious consequences associated with an actual or potential event under consideration. It relates to quantities such as the probability that the specific event may occur and the magnitude and character of the consequences.

Safety Culture

The assembly of characteristics and attitudes in organisations and individuals which establishes that as an overriding priority, the protection and safety issues receive the attention warranted by their significance.

Surveillance

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

Technical Specifications for Operation

A document approved by the regulatory body, covering the operational limits and conditions, surveillance and administrative control requirements for safe operation of the nuclear or radiation facility. It is also called as 'operational limits and conditions'.

SPECIAL DEFINITIONS

(Specific for the Present Guidelines)

Condition Monitoring

Continuous or periodic tests, inspections, measurement or trending of the performance or physical characteristics of structures, systems and components to indicate current or future performance and the potential for failure.

Creep

Time, temperature dependent deformation of a material under load.

Erosion Corrosion

A conjoint action involving corrosion and erosion in the presence of a moving corrosive fluid, leading to an accelerated loss of material.

Fatigue

The phenomenon leading to fracture under repeated or fluctuating stresses having a maximum value less than the ultimate tensile strength of the material.

Hydrogen Attack

A loss of strength and ductility of steel by high-temperature reaction of absorbed hydrogen with carbides in the steel resulting in decarburized layer and/or internal fissuring (surface defects consisting of narrow openings or cracks).

Hydrogen Blistering

The formation of blisters on or below a metal surface from excessive internal hydrogen pressure.

Hydrogen Embrittlement

A permanent loss of ductility in a metal or alloy caused by hydrogen in combination with stress, either an externally applied or an internal residual stress.

Pitting

Corrosion of a metal surface, confined to a point or small area that takes the form of cavities.

Stress Corrosion Cracking (SCC)

Growth of Crack formation due to simultaneous action of tensile stress and a reactive environment.

CONTENTS

1. INTRODUCTION

1.1 General

Heavy water is a prescribed substance used in pressurised heavy water reactors (PHWR) as a moderator to thermalise the fast neutrons generated in the fission reaction and also as coolant to carry away the heat of the nuclear reaction to the secondary side for generating the steam. The production of heavy water in India is done using chemical exchange processes viz. hydrogen sulphide-water bi-thermal exchange process and ammonia-hydrogen mono-thermal exchange process. Alternate technology, of water ammonia (H_2O-NH_3) exchange process was developed and a plant was set up for demonstration purpose and it is presently under shutdown. The production of heavy water involves handling of hazardous materials such as synthesis gas, ammonia, potassium metal, potassium amide and hydrogen sulphide operating at varying pressures ranging from vacuum to high pressure and at operating temperature ranging from very low temperature to very high temperature. Apart from this, there is only single pressure boundary between hazardous fluid and that of environment. Therefore, any accidental release of the hazardous fluids will have a consequence on the plant, operating personnel, general public and environment. Hence, it is important that all the systems containing hazardous fluids have to be maintained in healthy condition to avoid failure during the course of service life of the heavy water plants (HWP) and should have adequate safety margin in the design.

The physical characteristics/integrity of Structures, Systems and Components (SSC) of the HWP may get affected due to various degradation mechanisms over a period of time. For maintaining integrity of plant and components, it is therefore required to identify/establish various forms of degradation mechanisms, rate of degradation, corrective actions thereof and acceptance limits. This can be achieved by establishing a systematic and formal assessment of the SSC which should be done at periodic intervals by comparing the available safety margins with the design safety margins. This systematic and formal assessment of SSC requires planning and implementing an effective life management programme at all stages of the HWP.

Careful assessment of the ageing characteristics of the SSC, factors influencing the ageing process and their consequences on safety margins and reliability is essential for planning and implementing timely actions for assuring safe operation of the HWP during its life time.

1.2 Objective

This document provides the guidelines detailing about the essential factors that are required to be considered for a comprehensive assessment of the ability of the SSC important to safety for performing their intended functions reliably as per design specifications. This document elaborates the requirements for planning and implementing an effective life management programme for the new HWP and presently operating HWP.

For implementing an effective life management programme for new HWP, all site related parameters and other design inputs, which influence the life, should be evaluated and accounted for in design, siting, construction and commissioning. Activities such as site selection, compilation of baseline data on environmental conditions, design, manufacturing, storage, construction and commissioning have influence on safety and life span of SSC. For the operating HWP, the technological obsolescence, changes in the regulatory requirements, operational feedback experience and failure data plays a crucial role in life management programme. This document provides detailed guidelines on the integrity assessment of SSC of Heavy Water Plants and life management programme during pre-operation (for new HWP) and operation phase (for operating HWP).

1.3 Scope

These guidelines cover aspects like screening of various SSC which are important to safety of both hydrogen sulphide and ammonia based HWP, degradation mechanisms of SSC during operation of the above HWP, factors influencing ageing, measures to mitigate ageing effects and organisational aspects of life management. The pre-operational life management considerations during siting and construction for new HWP and life management considerations for the existing operating HWP have been separately brought out in this document.

This document is applicable only for HWP. Decommissioning aspects are not covered in this document.

2. LIFE MANAGEMENT PLAN

2.1 Life Management Plan

Life management plan is a systematic and formal assessment of integrity/fitness for service/residual life of various structures, systems and components (SSC) done at periodic intervals to judge the health of the plant and provide suitable measures to be taken for its safe and uninterrupted operation. Life management plan of heavy water plants should cover the various stages from siting continuing through design, construction, commissioning, operation and extended phase of operation. Life management plan must ensure acceptable safety performance during operating phase and extended phase of operation. Special attention is required during the extended phase beyond design life of operation due to the ageing effect.

2.2 Rationale for Life Management Plan

Existing/implemented programmes related to various activities and management of HWP (operation, maintenance, in-service inspection and surveillance) for safe operation are detailed in other plant specific documents prepared by HWP. Life management, in general, coordinates all these activities. Life management addresses issues like understanding, predicting and detecting effects of ageing and measures for mitigating actions. It brings to the notice of the designers, manufacturers and operating organisation, the need for effective ageing management of SSC. It can be best accomplished under systematic umbrella type programme that coordinates existing activities relevant to ageing management.

While formulating the life management programme, the following aspects should be included:

(a) Degradation of plant SSC caused by a combination of ageing mechanism and premature degradation during various phases of plant life.

(b) Understanding the role of service environment and various degradation mechanisms in causing premature ageing and implementing suitable operation and maintenance (O & M) practices for minimising degradation.

(c) Upgrading of safety levels to the extent feasible with increase in knowledge and improvement in technology.

2.3 Licence Renewal for Operation

License is issued to HWP for operation as per the Atomic Energy (Factories) Rules, 1996. During operation, aspects important to safety are assessed at regular intervals. Renewal of License for operation for further period is issued after assessment of safety performance and thorough review of inspection reports of SSC of the HWP.

Well before the end of licence period, license renewal for further periods of operation is to be applied. The basic approach and criteria for such licence renewal are as follows:

(a) Original design safety levels should be met

(b) Upgradation in plant carried out to achieve safety requirements as stipulated for heavy water plants by regulatory body.

(c) Changes in site characteristics.

(d) Safety analysis should be reviewed and updated to current standards relevant to HWP.

2.4 Phases of Life Management

The life management should be carried out in two distinct phases: pre-operational and operational (Refer Appendix-1). These are discussed in sections 3 and 4 respectively.

2.5 Elements of Life Management

The main elements of life management are as follows:

(1) Ageing considerations

(2) Technological innovations

(3) Generic safety issues

(4) Changes in the safety practices/regulatory requirements.

2.5.1 Ageing considerations

Ageing considerations should be made in the following three-steps:

(i) Selection of SSC for evaluation of ageing studies.(Refer Appendix-2)

- Active components
- Passive SSC components.

(ii) Studies of the selected SSC for degradation (Refer Appendix-3A and 3B) such as,

- Material properties, specifications and parameters considered for design life of components and designed life.

- Operating conditions and stressors.
- Degradation mechanism and in-built condition monitors.
- Operational experience feedback.
- Research and development on specific component.
- Operation, surveillance and in-service inspection (ISI) data.

(iii) Appropriate monitoring and corrective actions.

The Ageing considerations in total should also consider the ageing of civil structures, instrument and control systems (I & C) and electrical cables and appropriate mitigation measures for life management should be considered in overall life management plan. The list of degradation mechanisms, affected materials and equipment for mechanical and civil structuresare are enumerated in Annexure-IA and Annexure-IB respectively.

2.5.2 Technological Innovations

It includes:

(a) upgradation of technology,

(b) change in specifications,

(c) change in standards, and

(d) discontinuation of product.

2.5.3 Generic Safety Issues

Over the operating experience from HWP and other similar plants, certain generic issues should be identified and accordingly modifications/improvements should be carried out. Research and development aimed at understanding failures due to ageing of components and materials, lead to improvement of component design and advancement of material technology.

2.5.4 Changes in Safety Practices/Regulatory Requirements

Over the life time of the plant, it is likely that there are significant changes in the safety practices and the regulatory requirements. The reasons for such changes range from the evolution of technology, changes in socio-economic conditions and societal outlook/expectations on safety, operational experience, international feedback, research findings, etc. The issues arising out of these aspects also need to be addressed as a part of life management.

The periodic reviews for license renewal or the reviews for continued plant operation should systematically address these aspects. The plant/utility/regulatory body (use as appropriate) as part of the review should identify and evaluate the current safety practices/regulatory requirements, which are relevant for the plant design/process/operation/hazard evaluation, etc. The source of this information could be feedback of operating experience of similar chemical/petrochemical industries/process etc. or research findings from the field of plant safety.

The evaluation should systematically compare the features (or factors) of the plant vis-à-vis the current state of art in terms of the safety practices/ requirements, to identify the strengths and weaknesses. The assessment should also address the feasibility (technological as well as economical) and usefulness of implementing the current features in the context of the plant. A reasonable basis for this could be a cost benefit analysis of such a modification, taking into account the projected remaining service life of the plant. Based on this review, a list of the up-gradation/modification that needs to be implemented should be arrived at, together with the implementation programme.

In areas where the weaknesses cannot be addressed, the utility/plant should come out with alternate provisions to address the weaknesses adequately or provide justifications for continued plant operation with the identified weaknesses, to the satisfaction of the regulatory body. The cost - benefit analysis could be one of the basis of such justification. In such cases, the regulatory body may decide on continued operation of the plant based on the detailed assessment of the justifications.

2. 6 Organisational Aspects of Life Management

Responsible organisation/operating organisation should have appropriate organisational set up to develop and implement life management plan. This plan should be conceived and implemented from the stage of site selection, through the life of the HWP. The organisations involved in siting, design, construction, commissioning and operation should participate in the life management plan. The following aspects are considered:

(a) Organisation of life management

(b) Human aspects and safety culture

(c) Infrastructural development

(d) Review of life management programme.

3. LIFE MANAGEMENT ASPECTS FOR PRE-OPERATIONAL PHASE

3.1 Life Management Considerations

This section covers the pre-operational phase of the life management of HWP. Pre-operational activities such as site selection, compilation of baseline data on environmental conditions, design, manufacturing, storage, construction and commissioning have influence on safety and life span of SSC. Therefore, it is important that life management aspects for SSC of HWP should be considered right from site selection phase to operation phase for ageing management. All site related parameters and other design inputs which influence the design life, should be evaluated and accounted for in design and construction. This chapter mainly addresses requirements for new plants.

3.2 Planning of Life Management

Planning of life management should start from the conceptual stage of the heavy water plant. Siting, design, construction, commissioning are the stages of the plant where activities important for life management are to be planned.

(a) Siting

(i) Designing of SSC considering effect of any aggressive environment at selected site.

(ii) Protection from external natural events such as storms, cyclones, flooding, seismic, fire, coastal erosion, tsunami etc.

(iii) The impact of adjoining facilities shall be considered for life management.

(b) Design

(i) Design of SSC taking into consideration, influence of various service conditions and selection of manufacturing processes etc.

(ii) Adequate provision for maintenance and replacement of equipment.

(iii) Provision for in-service inspection.

(iv) Effects of interruptions in power supply, variations in frequency and voltage for sustained periods should be taken into account while preparing specification of SSC.

(c) Construction

   (i) Selection of appropriate fabrication processes.

   (ii) Use of appropriate procedures for storage, handling, erection and inspection of SSC.

   (iii) Maintaining appropriate environment and following proper procedures during erection of equipment.

(d) Commissioning

   (i) Collection of baseline data/Pre-Service Inspection data.

   (ii) Non-conformance observations and corrective actions taken.

3.3 Procurement, Manufacturing and Storage of Equipment

The organisation should ensure that the procured equipment/components meet the design specifications. The design specifications should cover technical and quality assurance (QA) requirements. The responsibility of the vendors should be defined and interface arrangements for approval and inspection should be specified.

Manufacturer/vendor of SSC important to safety should establish and implement QA programme, the level of which should commensurate with the safety significance of the items manufactured. The organisation should ensure compliance of QA requirements by vendor.

Well established procedures and storage conditions should be established and maintained for spares and sub-assemblies to prevent degradation. Procedure for storage of SSC important to safety should be established to avoid deterioration prior to commencement of operation considering aggressive environment like saline atmosphere or corrosive pollutants. Storage arrangements during manufacture, transportation and at site, prior to commencement of erection/construction should be carried out to minimise those factors which influence ageing.

3.4 Considerations during the Construction and Erection Stage

QA programme should be instituted to include the requirements for quality assurance checks, qualified personnel, procedures and documentation which should form part of approved procedures and records are to be handed over to the commissioning group for generation of baseline references, especially for in-situ fabricated equipment.

3.5 Commissioning and Pre-operational Data Collection

During commissioning, baseline data should be collected for comparison and trending during operation for detecting degradation due to ageing.

Benchmark should be established for monitoring of foundation settlement for safety related SSC e.g. exchange towers, waste stripper in H_2S based HWP, high power rotating equipment like compressors, turbo generators etc. Comparison from a reference point over a period of time will provide useful information for understanding the progressive behavior for foundation settlement and ageing of the SSC. The baseline information data for ageing management includes the following:

(a) expected degradation mechanisms,

(b) design specifications (including design service conditions and design service life cycles),

(c) equipment specifications (qualified life, normal/unusual service conditions, procurement, storage, installation, operation and maintenance specification),

(d) test conditions,

(e) manufacturing stage inspection and test data (including materials data),

(f) installation and commissioning data (e.g. data on startup test, baseline vibrations, pre-service inspection),

(g) information on design changes,

(h) problems/difficulties/deficiencies noted during commissioning.

4. LIFE MANAGEMENT ASPECTS DURING OPERATION PHASE

4.1 General

Heavy water plants in India have been operating for past 30 years and the degradation of the plant components and equipment are being monitored continuously by implementing various condition monitoring techniques and by following well developed in-service inspection (ISI) programme. These techniques provide systematic data and trend analysis regarding degradation of the plant equipment and structures thereby providing the basic information for evaluating ageing characteristic of the SSC. All these pre-existing programmes are important inputs for formulating an effective ageing management plan during the operation phase.

This chapter describes the requirements to be complied with during operation. All the operating as well as proposed HWP should formulate and implement the typical ageing management plan in operation phase.

4.2 Life Management Aspects during Operation Phase

Typical ageing management programme for operational phase involves coordinating the ageing management activities for SSC, managing SSC degradation mechanisms, detecting and assessing ageing effects and taking corrective actions. The typical ageing management plan for operational phase is described in Appendix-1.

4.2.1 Classifications of Structures, Systems and Components

The purpose of this section is to achieve a graded approach in life management. A typical classification is given below.

4.2.1.1 Class A SSC

Class A SSC, are normally not replaceable and therefore they may limit the life of a HWP. They are designed to retain the required safety margin during lifetime, considering degradation caused by ageing, operational occurrences and design basis accident conditions, if any. Specific surveillance and periodic assessment is carried out considering operating experience, current knowledge on degradation mechanisms, pilot studies on degradation mechanisms, online monitoring systems and critical components.

Examples : Exchange towers, ammonia converter, load bearing concrete and steel structures etc.

4.2.1.2 Class B SSC

Class B SSC have limited accessibility and are difficult to be replaced due to their layout and/or requires long shutdown period or exceptional logistics. Condition monitoring, trending, preventive maintenance and ISI are possible to manage ageing effects.

Examples : Large heat exchangers, first isolation valves and interconnection valves on the gas lines, large vessels, turbine casing and generator stators, emergency dump valves, flare stack, hyper compressors, boosters, cracker furnace, waste heat boilers etc.

4.2.1.3 Class C SSC

For these SSC preventive maintenance, ISI and condition monitoring is possible to manage ageing. They are replaced / repaired in a planned manner during operating phase.

Examples: General heat exchangers, process and dump tanks, control valve, safety relief valves, fire and emergency cooling water systems, start-up transformers, emergency and black out diesel generator sets, class I, II and III power supplies, emergency instrument air system for critical control operation etc.

4.3 Prioritisation of SSC

In formulating the life management plan, priorities have to be assigned to SSC based on graded approach, operating experience on ageing and premature failures. Accordingly, safety significance is prioritised as high, medium and low.

4.3.1 High Priority

High priority SSC will have serious impact on plant safety and on intended design safety margins. They need extensive and intensive monitoring, assessment and timely corrective measures. The plant is required to be shutdown till acceptable interim or permanent corrective measures are implemented.

Examples : Non- availability of flare, non-availability of nitrogen at required pressure, control room habitability, non-availability of emergency power supplies, non-availability of sealant water system, H_2S bullets etc.

4.3.2 Medium Priority

Medium priority SSC also has significant impact on plant safety. After implementing interim corrective measures, plant operation may continue for limited time based on risk assessment.

Examples : Restricted availability of fire water pumps, restricted availability of deluge systems etc.

4.3.3 Low Priority

Low priority SSC has no significant impact on plant safety. Plant operation can continue without any interim measures. Corrective measures should be implemented within a stipulated period.

Examples : Non- availability of standby pumps/compressors.

4.4 Monitoring and Mitigation of Ageing during Operation

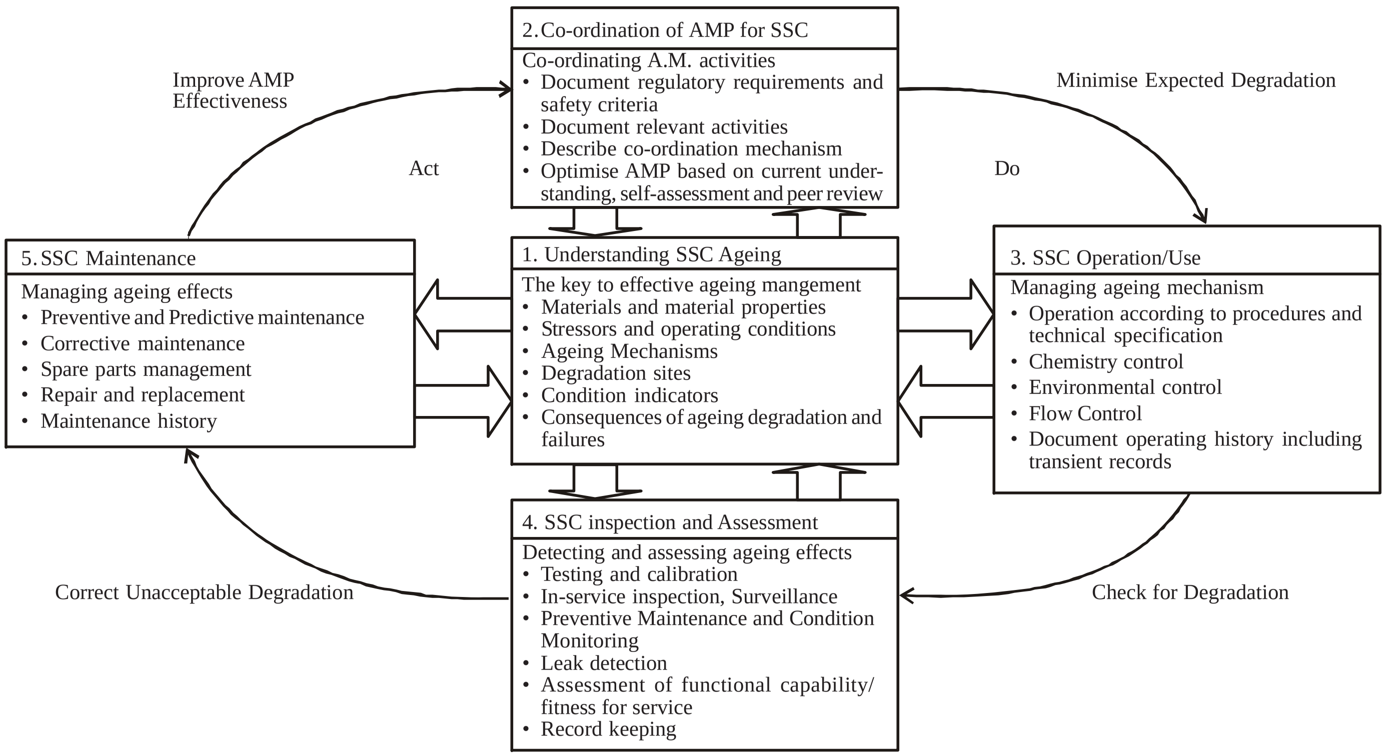
The design life of the SSC considering various service conditions and factors would influence its service life. This will form the basis for the ageing monitoring for assessing residual life. For example, corrosion monitoring and influence of the number of thermal cycles, pressure cycles, low/high frequency operations, over-pressure incidents etc. should be evaluated at specified intervals and corrective measures shall be taken to enhance the service life. Data from condition monitoring, surveillance and ISI of selected SSC gives basic information regarding degradation and should be used to detect and monitor degradation. Accordingly, suitable mitigating measures like controlling operating parameters, planning maintenance programme, modifications etc. should be taken for effective life management of SSC.

Appropriate data such as baseline data, operating history data and maintenance history data should be made available and maintained for selected SSC for developing effective life management strategies for SSC. In case the baseline data is not available, validated available data from first major turn-around should be considered for pre-service inspection. Data such as thickness measurement should be considered from first major turn-around.

APPENDIX-1

(Refer Section 2.4)

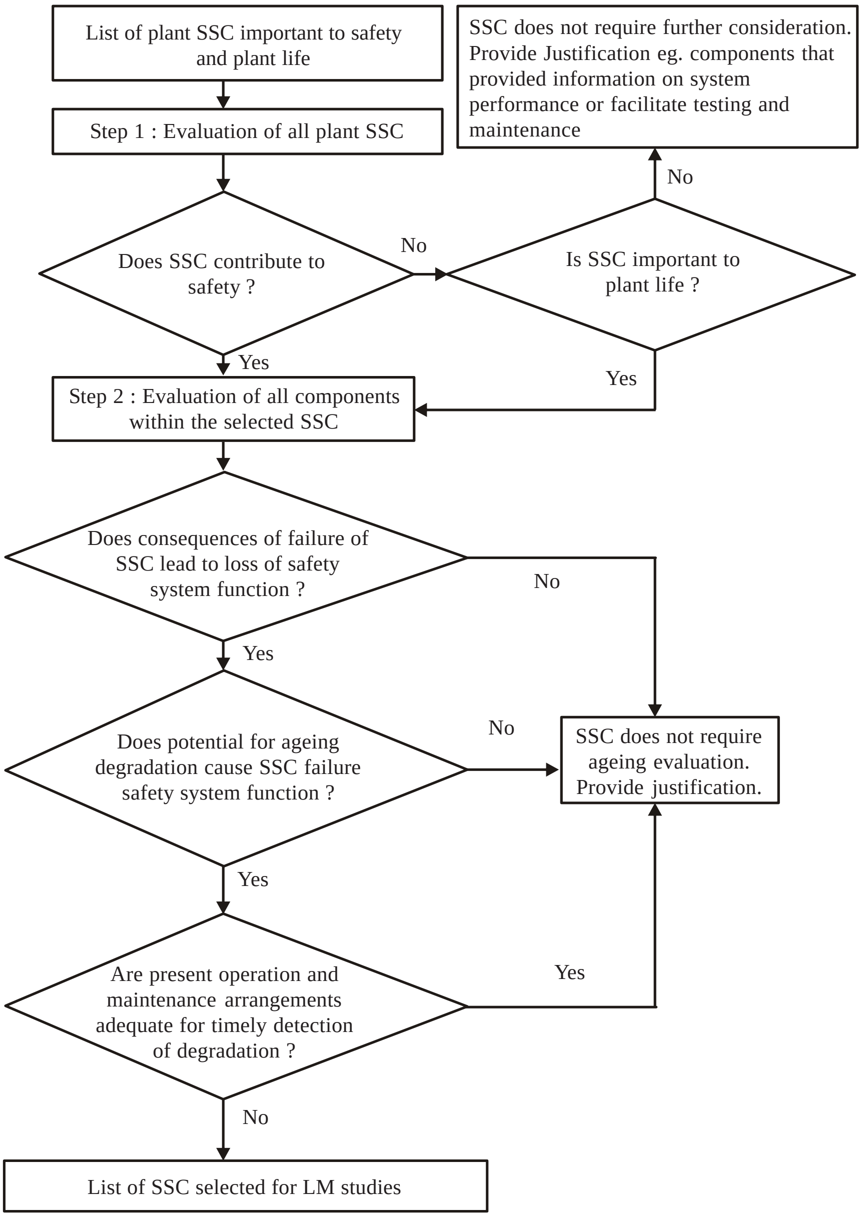
TYPICAL AGEING MANAGEMENT PLAN FOR OPERATIONAL PHASE



APPENDIX-2

(Refer Section 2.5.1)

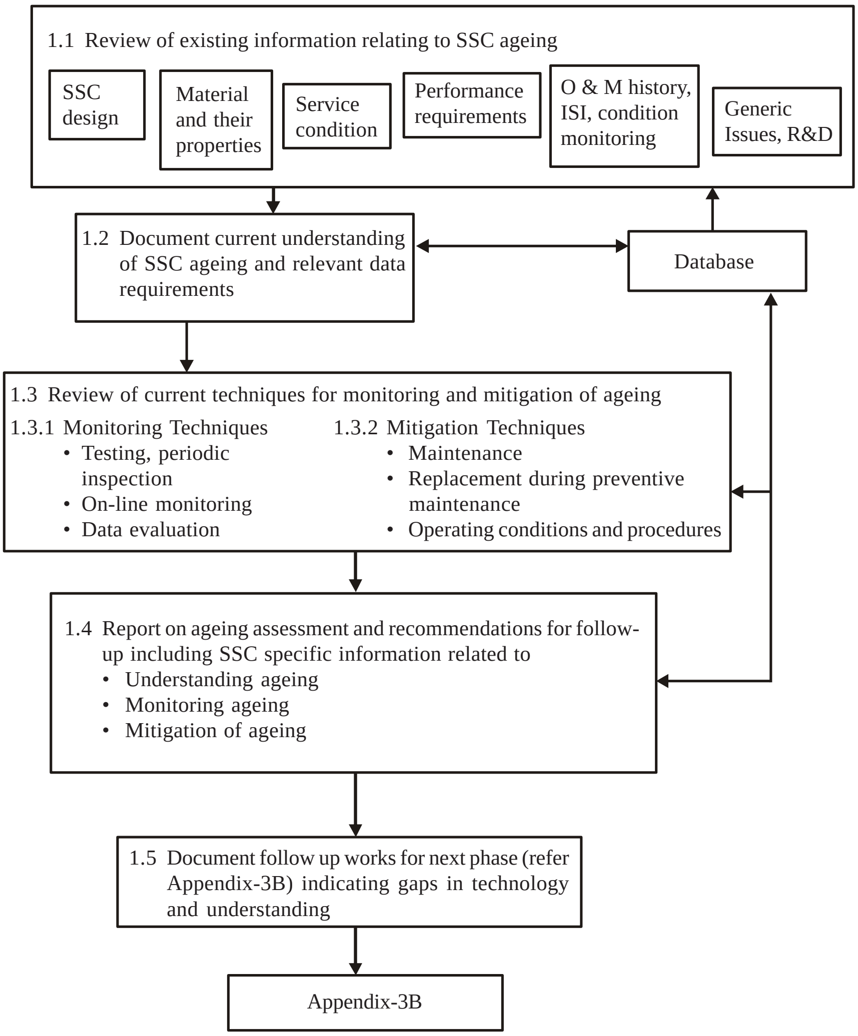
SELECTION PROCESS FOR SSC



APPENDIX-3A

(Refer Section 2.5.1)

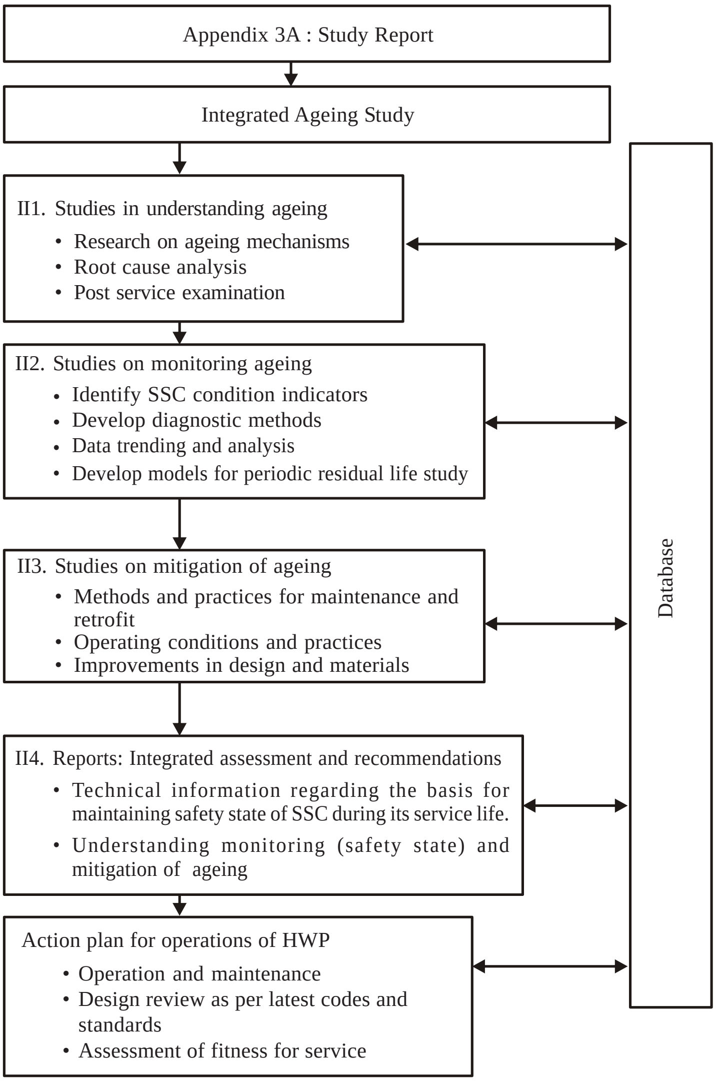
METHODOLOGY OF DEGRADATION STUDIES OF SSC



APPENDIX-3B

(Refer Section2.5.1)

METHODOLOGY OF DEGRADATION STUDIES OF SSC



ANNEXURE IA

(Refer Section 2.5.1)

ENVIRONMENTAL STRESSORS, DEGRADATION MECHANISMS AND AFFECTED/SUSCEPTIBLE MATERIALS AND COMPONENTS

(TYPICAL LIST)

Sr. No.	Stressors/ DegradationMechanism	Susceptible Materials and Components
1	General corrosion, pitting	Low to no flow component, process/cooling water system (pump, pipe, valves, HX) standby process systems, fire water system.
2	Stress corrosion cracking on internal/external surfaces (at low and high temperature).	Wet insulation with high chloride, off- normal chemistry parameters (chloride, pH, sulfides, ammonia), stressed component due to welding, rolling, cold- working. SG, HX tubes and condenser tubes, SS-304 / 316 pipe lines.
3	Erosion corrosions	Carbon steel (CS) piping and pumps, heat exchangers, waste heat boilers etc.
4	Crevices corrosion (low and high temperature)	Crevices and hideout regions, stagnant areas, sleeved region of pipe, stub-shafts, welds with back-up rings, valve/pump drain line area in casing
5	Microbial influenced corrosion (low temperature)	Service/process water equipment (pumps, pipes, valves, HX) where hydro test is carried out with bacteria contaminated water, ingress of dirt/mud in equipment and lay up with water.
6	Corrosion fatigue (Thermal and vibration)	Thermal mixing regions in carbon and alloy steel components.
7	Fatigue (Thermal cycling)	Rotating equipment support and piping attached to large component (piping and hanger support)
8	Weld related cracking	
8. 1	Lack of fusion, hot ductility, ferrite depletion, crevice formation (high and low temperature)	Similar materials welds, wrought materials to casting welds, low ferrite filler welds and seam welds.

8. 2	Dilution zone cracking (HAZ weld cracks)	Dissimilar material welds (CS to SS), SS-SS welds
9	Low temperature sensitization	Stainless steel components
10	Thermal embrittlement (high temperature)	Ferrite and cast SS components
11	Mechanical wear/fretting	Mechanical rotating equipment ball bearing fit-up area on the shaft, impeller vanes and turbine blades.
12	Oxidation due to environment	Relay and breaker contacts, lubricants, insulation materials associated with components (cables varnish etc.)
13	Creep	High temperature components
14	Hydrogen attack	Due to hydrogen pick-up during corrosion of CS
15	Abnormal rise in voltage and frequency	Cables, relays and windings

ANNEXURE-I B
(Refer Section 2.5.1)

DEGRADATION FACTORS AFFECTING THE PERFORMANCE OF SAFETY RELATED CONCRETE STRUCTURES
(TYPICAL LIST)

(a) Concrete

Ageing Stressors/ Service Conditions	Ageing Mechanism	Ageing Effect	Potential Degradation Sites	Remarks
Percolation of fluid through concrete due to moisture gradient	Leaching and efflorescence	Increased porosity and permeability; lowers strength	Near cracks; areas of high moisture percolation	Makes concrete more vulnerable to hostile environment; may indicate other changes to cement paste; unlikely to be an issue for high quality, low-permeability concretes
Exposure to alkali and magnesium sulphates present in soils, seawater or groundwater	Sulphate attack	Expansion and irregular cracking	Subgrade structures and foundations, sodium sulphide in H_2S based HWP	Sulphate-resistant cements or partial replacement of cements used to minimise potential occurrence
Exposure to aggressive acids and bases	Conversion of hardened cement to soluble material that can leach	Increased porosity and permeability	Local areas subject to chemical spills; adjacent to pipework carrying aggressive fluids	Areas prone to attacks are protected by suitable lining/coating
Combination of reactive aggregate, high moisture levels and alkalis	Alkali aggregate reactions leading to swelling	Cracking; gel exudation; aggregate pop-out	Areas where moisture levels are high and improper materials are utilised	Eliminate potentially reactive materials; use low alkali-content cements or partial cement replacement
Cyclic loads/ vibrations	Fatigue	Cracking; strength loss	Equipment/ piping supports	Localised damage; fatigue failure of concrete structures unusual

Exposure to flowing gas or liquid carrying particulates and abrasive components	Abrasion; Erosion; Cavitation	Section loss	Cooling water intake and discharge area structures	Appropriate hydraulic design and other protection measures
Exposure to thermal cycles at relatively low temperatures	Freeze/thaw	Cracking; spalling	External surfaces where geometry supports moisture accumulation	Air entrainment utilised to minimise potential occurrence
Thermal exposure/ Thermal cycling	Moisture content changes & material incompatibility due to different thermal expansion values	Cracking; spalling; strength loss; reduced modulus of elasticity	Near hot process and steam piping	Generally an issue for hot spot locations; can increase concrete creep that can increase pre-stressing force losses
Consolidation or movement of soil on which structure footings are located	Differential settlement	Equipment alignment, cracking	Connected structures on independent foundations	Allowance is made in design
Exposure to water containing dissolved salts (e. g. seawater)	Salt crystallisation	Cracking	External surfaces subject to salt spray; intake structures	Minimised through use of low permeability concretes, sealers, and barriers

(b) Mild Steel Reinforcing

Ageing Stressors/ Service Conditions	Ageing Mechanism	Ageing Effect	Potential Degradation Sites	Remarks
Depassivation of steel due to carbonation or presence of chloride ions	Composition or concentration cells leading to corrosion	Concrete cracking and spalling; loss of reinforcement cross-section	Outer layer of steel reinforcement in all structures where cracks or local defects (e.g. joints) are present	Prominent potential form of degradation leads to reduction of load-carrying capacity
Elevated temperature	Microcrystalline changes	Reduction in yield strength and modulus of elasticity	Near hot vessels and piping	Of significance only where temperature exceeds 200^0C
Cyclic loading	Fatigue	Loss of bond to concrete; failure of steel under extreme conditions	Equipment/ Piping supports	Localised damage; fatigue failure of concrete structures unusual

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LIST OF PARTICIPANTS

EXPERT COMMITTEE FOR PREPARATION OF DOCUMENT ON LIFE MANAGEMENT OF HEAVY WATER PLANTS

Dates of meeting:	February 2, 2009	March 26, 2009	May 29, 2009
	July 17, 2009	January 11, 2010	February 22, 2010
	March 11, 2010	May 4, 2010	June 7, 2010
	June 21, 2010	July 8, 2010	July 27, 2010
	September 7, 2010	October 26, 2010	November 11, 2010
	December 20, 2010	February 4, 2011	March 1, 2011
	April 26, 2011	June 9, 2011	July 26, 2011
	September 16, 2011	September 23, 2011	November 29, 2011
	December 27, 2011	January 6, 2012	February 15, 2012
	August 13, 2012		

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Dates of meeting:	December 19-20, 2013 January 23-24, 2014

Members of ACSD-FCF:

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Shri P.B. Kulkarni	:	BARC (Former)
Shri S. Majumdar	:	BARC (Former)
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LIST OF REGULATORY DOCUMENTS RELATED TO HEAVY WATER PLANTS AND INDUSTRIAL SAFETY

S. No.	Safety Series No.	Title
1.	AERB/NF/SS/FPS (Rev.1); 2010	Standard for Fire Protection Systems of Nuclear Facilities
2.	AERB/HWP/SG-1	Safety Aspects in Design and Operation of Heavy Water Plants
3.	AERB/HWP/SG-2	Life Management of Heavy Water Plants
4.	AERB/NRF/SG/IS-1 (Rev. 1); 2011	Control of Works
5.	AERB/SG/IS-2; 2001	Preparation of Safety Report of Industrial Plants other than Nuclear Power Plants in the Department of Atomic Energy
6.	AERB/SG/IS-3; 2004	Guidelines for Personal Protective Equipment
7.	AERB/SG/IS-4; 2005	Guidelines for Pre-employment Medical Examination and Fitness for Special Assignments
8.	AERB/SG/EP-3; 2000	Preparation of On-site Emergency Preparedness Plans for Non-nuclear Installations
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