Role of NDE in Regulatory Oversight of Nuclear Power Plants

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Abstract

Atomic Energy Regulatory Board (AERB) was constituted in 1983 to carry out regulatory and safety functions for independent assessment of safety status in all the stages of nuclear and radiation facilities. Quality of safety related systems, structures and components (SSCs) of nuclear power plants (NPPs) plays crucial role in achieving the specified safety objectives. Non-destructive examinations (NDE) of the NPP components is one of the important means to determine their quality.

AERB carry out safety review of pre-service inspection and in-service inspection (PSI/ ISI) program of NPPs to check adequacy of coverage of SSCs for inspection, suitability of specified NDE technique, inspection procedures, frequency and competence of inspection personnel. AERB ensures implementation of PSI/ISI programme by conducting safety review and regulatory inspections, prior to issuance/ renewal of regulatory consent.

NDE of safety related SSCs of NPPs is carried out during different stages of manufacturing in accordance with approved Quality Assurance Plan (QAP) and complying with the specified requirements given in applicable Codes/Standards. Baseline data is generated for all the safety related SSCs by implementing the PSI programme. During operation stage of NPPs, status of the safety related components is monitored by carrying out in-service inspection (ISI) using the same NDE methods as those of PSI and results are compared with the baseline data for assessment of service induced degradation.

This paper also covers certain challenges faced during review and assessment of the adopted NDE approach for SSCs of different NPP designs.

Introduction

Activities concerning establishment and utilization of nuclear facilities and use of radioactive sources are to be carried out in India in accordance with the provisions of the Atomic Energy Act, 1962. In pursuance of the objective of ensuring safety of members of the public and occupational workers as well as protection of environment, Atomic Energy Regulatory Board (AERB) was constituted in 1983. The AERB is entrusted with responsibilities, among others, to lay down safety standard and frame rules and regulations in regard to the regulatory and safety requirements. AERB has established consenting process to carry out independent assessment of safety during all the stages of nuclear and radiation facilities (NRF) to meet the safety objectives.

As per the consenting process specified in safety code (AERB/SC/G) and safety guides published there under (e.g. AERB/NPP&RR/SG/G-1 for Nuclear Power Plants), the Consentee is required to submit applications and supporting documents containing specified information to AERB for each identified stages of NRF. AERB carries out multi-tier safety review and regulatory inspections to verify compliance with the safety requirements, prior to issuance/ renewal of regulatory consents. This paper brings out salient aspects related to regulatory review of Pre-Service Inspection/In-service Inspection (PSI/ISI) program of Nuclear Power Plants.

Role of NDE in regulatory oversight

During the operating life of NPP, its components are exposed to influences whose individual or combined effect cannot be fully predicted with desirable accuracy level to ensure safety. These influences are stress, temperature, irradiation, hydrogen absorption, corrosive attack, vibration and fretting, all of which depend upon time and operating history. These influences may result in changes in material properties such as embrittlement, fatigue, formation and/or growth of flaws and ageing.

NDE helps in assessment of quality of the SSCs by monitoring the deterioration in condition or growth of earlier detected flaws, before the components fail. As part of consenting process, PSI/ISI program is required to be submitted by the Consentee in support of Application for commissioning. The inspection program, among others, should include: (a) Criteria for selection of SSCs for PSI/ ISI (b) Responsibilities (c) Examination areas (d) Methods of NDE (e) Applicable codes and standards (f) Extent of examination (g) Examination interval (h) Reporting of the inspection data (i) Examination personnel (j) Analysis of data and (k) audits. The PSI/ISI program and the inspection results are reviewed by AERB for acceptability.

SSCs of an NPP are classified based on their intended safety functions and consequences of failure. Quality assurance program is based on application of graded approach and different QA requirements, including NDE are specified accordingly. Inspection of SSCs using different NDE methods is carried out at different stages as specified in approved QA Plans and PSI/ISI Program.

Various NDE methods (VT, PT, ET, MT, RT and UT etc.) are used during PSI/ISI for flaw characterization (detection, location, finding size/ shape/ orientation/ nature of flaws). Selection of NDE method and test parameters is done keeping in view the type of flaw and material degradation. Quality of NDE results depends on capability of test equipment, effectiveness of test procedures and competence of testing personnel. These factors need to be addressed during internal and external audits. Implementation of approved PSI/ISI program is verified during regulatory inspections carried out by AERB. Acceptability of NDE results obtained during PSI/ISI is important consideration in decision making process related to issuance/ renewal of regulatory consents.

Design Considerations for PSI/ISI

One of the reasons of products' failure in service can be attributed to the errors in the product design/ development, particularly with respect to the specification of inspection and testing. Some products with complex geometry (size and shape) may require more than one NDE methods for thorough inspection. In certain cases full inspection using any NDE method may not be possible due to geometry or accessibility.

In order to establish and implement the PSI/ ISI programme effectively, considerations that should be taken into account at design stage itself, among others, are the accessibility, provisions for shielding, removal/ storage and installation of structural members/ necessary supports required for inspection, provision to enable examinations remotely, provision for decontamination, selection of materials/ weld configuration, provision for required repair or replacement, provision of test coupons, provision of power supply and instrumentation cables for PSI/ISI equipment and instruments which are required to be used for inspection.

A thorough knowledge of capabilities and limitations of the NDE methods is important for design engineers who specify the inspection requirements. Design quality assurance should consider the above mentioned factors regulatory requirements. It can be ensured if the engineering teams include

qualified NDE personnel. Selection of the appropriate sample size for NDE is another challenge often faced by the design engineers. Site conditions should be kept in mind while analyzing the test results based on ideal laboratory conditions.

At the procurement stage, technical specifications and purchase orders need to be reviewed by the qualified NDE personnel to ensure that proper NDE requirements are specified. Subsequently, NDE procedures and techniques submitted by the suppliers should be reviewed and approved by the authorized and qualified NDE personnel.

General Criteria for Examinations

The systems and components, piping thereof (including supports) subjected to inspections, should include:

a) Pressure boundary of reactor coolant or any other systems whose failure may result in a significant release of radioactive substances.
b) Systems essential for safe reactor shut down and/or safe cooling of nuclear fuel in the event of process system failure.
c) Other systems and components whose dislodgement or failure may put in jeopardy the integrity of the system mentioned in (a) or (b) above, or both.

Extent of Examination

Philosophy followed to determine extent of inspection and the inspection intervals of SSCs depend upon the applicable codes/ standards for particular reactor designs (PHWRs, BWR, VVER, and PFBR). Extent of inspection and the inspection interval are governed by the categorization of SSCs and inspection areas of the NPPs.

Scheduling of PSI and ISI

PSI is required to be performed either after the component hydrostatic pressure test or before the component hydrostatic pressure test provided that a confirmatory examination is performed after the component hydrostatic pressure test and the results indicate no significant change. The PSI shall be carried out for all components which are to be subjected to ISI. When a component is repaired or replaced, an initial examination of that component shall be carried out in line with PSI. The inspection techniques used during PSI should be identical to those envisaged during ISI.

Areas of Examinations

The inspection areas include piping, vessel, pumps, valves, steam generators/ heat exchangers (Welds and Tubes), Coolant Tubes (in PHWR), supports and Snubbers. Safety surveillance of high energy systems of secondary cycle piping are also included from Flow Assisted Corrosion (FAC) Considerations.

Quality Assurance in PSI/ISI

The quality assurance during PSI/ISI is intended to ensure that:

- Codal requirements are documented in PSI/ISI Manual, which is reviewed by AERB.
- PSI/ISI are carried out as per the approved Manual.
- Effective implementation is ensured by Audit (internal audit by Site QA and external audit by NPCIL-HQ).

Following are the Key Elements of Quality Assurance in PSI/ISI programme:

a) Management Responsibilities

Responsibilities related to PSI/ISI activities should be clearly defined. These activities typically include resourcing, planning and scheduling of NDE activities. It should also include health and safety aspects of the operators, as an integral part of the planning for NDE. Public safety should be considered, particularly in the case of field radiography. Preparations for RT should consider ALARA (As Low As Reasonably Achievable) principles. In addition to the resourcing and scheduling, the work management for NDE operations should also consider the following:

- Site clearance for carrying out the NDE operations
- Preparations for field inspection, such as scaffolding, and adequate lighting
- Installation/ removal of radiation shielding or insulation
- Surface preparations for the specimen to be tested
- Training for handling hazardous chemicals
- Post-inspection cleaning of the component
- Disposal of hazardous chemicals,
- Emergency support for unplanned events, including fire hazards, and
- Housekeeping

It should be joint responsibility of the qualified NDE personnel and the Management to ensure the personnel safety and the safety of the equipment while performing the operations. In addition, Management should consider all human factors that could affect the performance of the NDE personnel. Regular review of the logbooks by the management helps in identifying the performance issues, and necessary corrective actions that can be taken to improve the overall efficiency of NDE operations.

b) Personnel Training, Qualification & Certification

Since each NDE method has certain advantages and limitations, proper application of the techniques and interpretation of the results requires the qualified NDE personnel, based on the knowledge, skill and experience in respective NDE methods should carry out the inspection as per applicable codes. Further, in the case of Radiographic Testing (RT), it is a regulatory requirement that only certified operators shall handle the exposure devices. It is the responsibility of the Management to ensure that the NDE personnel are adequately qualified and certified prior to engaging them for the job.

c) Facilities and Equipment

Adequate facilities and equipment are necessary for achieving optimum results in NDE. Automated inspection techniques in several NDE methods, combined with the computerized vision systems, are contributing significantly to the productivity and quality. Not only the automation improves the efficiency of inspection, it also helps in increasing the reliability of NDE by minimizing the 'human errors' such as operator fatigue in routine operations. Therefore, creating and maintaining the suitable and adequate facilities and test equipment are among the key responsibilities of the management to maintain the 'Quality Assurance in NDE'.

d) NDE Technique and Procedures

The purpose of the NDE procedure is to ensure that the inspection technique is applied correctly and consistently so that expected results can be achieved with confidence. NDE procedures should be reviewed and approved by the authorized and qualified personnel in the respective NDE methods. An NDE procedure should identify the scope and limitations of the test, personnel qualification requirements, health and safety precautions, surface preparation

requirements, equipment and calibration standards to be used, applicable techniques, reference codes and standards, acceptance criteria and the records to be maintained. Mock-up trials shall be carried out to qualify the inspection procedures, inspection personnel and equipment.Also, the NDE procedures should provide clear instructions on the pre and post-cleaning of the test specimen, specifications of the consumables used in the NDE and post-NDE treatment (e.g. demagnetization), as required. A precautionary checklist in the NDE procedure would help to assure that these steps are promptly completed.

e) Calibration Standards

The NDE techniques should clearly identify the specific calibration standards to be used during the test set-up, in order to assure the sensitivity and resolution of the test results. For some applications, special calibration blocks should be prepared to suit the geometry (thickness and curvature range) of the test specimen. The material properties and geometry of calibration standards should closely match the characteristics of the test specimen.

The specified calibration checks should be carried out using the actual system employed under site conditions, where calibration in laboratory conditions using reference/ calibration standards differ from actual site conditions. These differences may arise due to use of different/ modified systems suitable for remote operation and associated specific instrumentation, such as use of long bunched cables, intermediate stage amplifiers, and due to differences in surface condition, temperature and pressure of component, etc. The NDE reports should invariably identify the calibration standard, against which the test system has been calibrated.

f) Acceptance Criteria for PSI and ISI

Acceptance standards for all the NDE methods (surface and volumetric) are required to be established before the start of the PSI/ISI programme. For cases where the acceptance standards are not in existence or are not relevant to the situation, these are to be established in consultation with regulatory body. Reporting standards should be established such that, when they have been reached, a margin still exists between them and the acceptance standards. When a flaw exceeding the acceptance standards is found during ISI, additional examinations are to be performed to include the specific problem area as additional number of analogous components.

g) Evaluations and Analysis of Results

The management should ensure that results of examinations are evaluated to determine compliance with acceptance standards. NDE personnel who interpret and evaluate the test results should be familiar with the applicable regulatory codes and standards in addition to the defined technical specifications. The ‘acceptance criteria’ play major role during inspection and investigation of the root cause analysis of failures. Interpretations of results are to be done by qualified personnel in the respective technique.

All relevant indications required to be identified and further investigated. Where the result of an examination does not comply with the acceptance standards, evaluation is to be done which should be extended to include the following:

(a) Notifying to AERB of the indication.
(b) Further examination by other non-destructive methods where practical.
(c) Determine disposition (repair or replacement)
(d) Submission of the disposition proposal to the AERB for acceptance.

Indications that do not comply with the acceptance standards may be considered as acceptable till the next ISI, provided it can be demonstrated by suitable analyses that integrity of the

component is still adequate, and predicted deterioration will not seriously reduce the integrity of the component prior to the next ISI.

h) Documentation

The documents necessary for adequate implementation of the ISI programme are required to be developed, maintained and made readily available. All relevant indications and pertinent information related to the indications (e.g. location, magnitude, length etc.), comparisons with previous examination results and evaluations should be documented and maintained in retrievable form.

i) Audits

All activities related to PSI/ISI are required to be periodically audited as per approved plan by qualified personnel to determine the adequacy of and adherence to established procedures, instructions, specifications, codes/ standards/ other applicable regulatory requirements and effectiveness of implementation. The audited group should report to the auditing organization the progress/ completion of corrective actions. The auditing organization evaluates the response and verifies the completion of necessary follow-up actions.

Challenges in Regulation of NPPs of different Reactor Designs

In certain cases challenges were experienced during review/ acceptance and implementation of the PSI/ISI program of different reactor designs, particularly with respect to following aspects:

a) Different criteria for selection of SSCs for PSI/ISI
b) Differences in specified inspection interval
c) Stages of inspections, stage of PSI and requirements related to confirmatory examinations
d) Criteria for acceptance of inspection observations during manufacturing stage and those for PSI/ISI
e) Inspection requirements for dormant systems
f) Implementation of intended inspection programme due to factors such as inaccessibility, limitations of available inspection tools/ techniques and higher radiation fields.
g) Non-availability of manufacturing stage inspection data for old plants (documentation of QA records)

At present, the available regulatory document on PSI/ISI is mainly addressing the inspection requirements of PHWRs and BWRs. AERB has undertaken revision of this document to address issues related to other types of NPPs also.

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