Ageing Management Aspects of Chemical based Fuel Cycle Facilities

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Abstract---*The Physical characteristics of Structures, Systems and Components (SSCs) of Fuel Cycle Facilities may change due to ageing process. This may reduce the safety margin provided in the design during course of service life. Also, most of these facilities operates under varying temperature, pressure and handles large inventory of corrosive, toxic & flammable fluids and having single line of pressure boundary between hazardous fluid & that of environment. This concern to the safe operation of the facility during the lifetime, safety against ageing phenomenon as well as proof of integrity. Therefore, it is important that all the SSCs containing hazardous fluid have to be maintained in healthy condition to avoid failure during course of service life and should have an adequate safety margin in the design. This can be achieved by systematic and formal assessment of the SSCs at periodic intervals i.e. by Preventative maintenance, Predictive Maintenance, Condition Monitoring, In-Service Inspection, Residual Life Assessment etc.*

This paper highlights various approaches utilized in the fuel cycle facilities to judge the health of the plant and suitable measures to be taken for its hazard free safe & uninterrupted operation.

Key Words: *Ageing,Preventative maintenance, In-Service Inspection, Residual Life Assessment*

1.0. Introduction:

During the operating life of a Fuel Cycle Facilities (FCF), its Structures, Systems and Components (SSCs) might be exposed to influences whose individual or combined effect cannot be fully predicted for the operating life of the plant. The most important influences are stress, high pressure & temperature, hydrogen related damages, corrosive attack and vibration etc. all of which depend upon time and operating history. These influences may result in changes in material properties such as corrosion, creep, fatigue, formation and/or growth of flaws and ageing.

The nature of chemicals used in the plant also plays a significant role in deciding the operating life of plant and its components. Most of the chemicals used in fuel cycle facilities are corrosive, toxic and flammable in nature. Also, there is a single line of pressure boundary between pressure vessel and environment. These factors may pose a threat to the public in case of failure of pressure boundary and release of toxic/flammable chemicals. So, a systematic and formal assessment of life of various structures, systems and components i.e. In- Service Inspection (ISI) programme, Preventative maintenance, predictive maintenance, condition monitoring of critical SSCs should be carried out at periodic intervals to judge the health of the plant and suitable measures to be taken for its hazard free safe & uninterrupted operation. Non Destructive Testing (NDT) and SSCs health assessment with regular condition monitoring plays an important role in achieving high degree of reliability of SSCs in fuel cycle facilities. Such Non-Destructive Testing for reliable inspection and Interpretations of service damage in the equipment over a period have provided adequate fitness for purpose and plant safety. This aspect is also helpful for the regulator for making decision on the continual operation of the facility. This paper highlights various ageing management approaches including advanced NDT techniques which is used in fuel cycle facilities for maintaining reliability, quality, safety, life extension of the plant and also provide confidence to the regulator for further extension of the plant beyond design life.

2.0. Ageing Management Aspects in Fuel Cycle Facilities:

Most of the Fuel Cycle Facilities (FCFs) in nuclear industry in India are being operated for more than 30 years and ageing of SSCs is a concern for safe and reliable operation of the plant beyond the design life. Also, most of these FCFs especially chemical facilities handles hazardous/toxic/flammablefluids such as synthesis gas, ammonia, potassium amide, chlorine& hydrogen sulphide etc., operates under varying

pressures& Temperature (Pressure: vacuum to 550 kg/cm^2(g)& Temperature: -33° C to 680°C) and operates under corrosive environment. Apart from this, there is only single pressure boundary between hazardous fluid and environment. Hence, it is important that all the SSCs containing hazardous fluids have to be maintained in healthy condition to avoid failure during course of service life and should have adequate safety margin in the design.
This can be achieved by establishing a systematic and formal assessment of the SSC at periodic intervals by ageing management of structures, systems and components. The various inspection and assessment techniques used for detecting & assessing ageing affects includes Testing & Calibration, Preventative maintenance, Predictive Maintenance, Surveillance, Condition Monitoring, In-Service Inspection, Fitness for Service etc. All these techniques are important inputs for formulating an effective ageing management programme during operation phase of the facility. Typical ageing management programme for operational facility involves coordinating the ageing management activities for SSC, managing SSC degradation mechanisms, detecting & assessing ageing effects and taking corrective effects.

Atomic Energy Regulatory Board (AERB), regulatory body for nuclear facilities has formulated various safety guides and guidelines for life and ageing management of SSCs for a safe operation of the facility throughout the lifetime.Thesesafety guides and guidelines elaborates the requirements for planning and implementing an effective life management programme in the facility and also provides guidelines detailing about the essential factors that are required to be considered for a comprehensive assessment of the ability of the SSCs important to safety for performing their intended functions reliably as per design specifications.

In life management programme, understanding and detecting ageing effects is one of the most important element for implementing an effective life management programme in any facility. Non–Destructive testing is one of the detectiontechniques that are being used immensely for reliable inspection and interpretations of ageing effects in the SSCs over a period of service. The various non-destructive testing techniques used in our Fuel Cycle Facilities are namely, Visual Testing (VT), Liquid Penetrant Testing (LPT), Magnetic Particle Testing (MPT), Ultrasonic Testing (UT), Eddy Current testing (ECT), radiography (RT), Phased Array Ultrasonic testing (PAUT), Time of Flight Diffraction (TOFD), High Voltage Spark testing etc. These techniques provide systematic data and trend analysis regarding degradation of the plant equipment and structures thereby providing the basic information for evaluating ageing characteristics of the SSC.

In chemical based FCFs, the major concern is the accidental release of corrosive, toxic and inflammable fluids thus posing threat to operating personnel and general public in surrounding. Therefore, it becomes pertinent to have comprehensive ageing management plan for critical equipment which handles large inventory of hazardous fluid. The list of some critical equipment identified in chemical based FCFs along with degradation mechanism and corresponding NDT used for detecting/monitoring degradations are mentioned below:

Sr. No.	Critical Equipment	Degradation Mechanism/ Degradation Indicators	PreferredNDT \ Mechanical Test
1.	Ammonia Cracker	• Precipitation Hardening, • Hydrogen attack • Creep, • Excessive Oxidation	Visual Testing (VT), Thickness detection by Ultrasonic, Dimensional checks, In-situ metallography, Hardness Test
2.	Ammonia Converter	• Uniform Corrosion,	Visual Testing (VT), Thickness Measurement

		• Hydrogen Attack	byUT, In-situ metallography, Hydro/Pneumatic test, Hardness Test
3.	Ammonia Exchange Towers	• External Uniform/ Atmospheric Corrosion, • Hydrogen Attack	UT, Thickness Measurement by UT, In-situ metallography, Hydro Test, Hardness Test
4.	H_2S based Exchange Towers	• Uniform Corrosion • Erosion-corrosion • Hydrogen Attack • Sulphide Stress Corrosion Cracking (SSCC) • Fatigue	Leak Survey, Visual Check (VT), Thickness Mapping, In-Situ Metallography (ISM), Hardness Mapping, Hydro testing, Hardness Test
5.	Heat Exchanger	• Erosion-corrosion at fluid Impingement location • Sulphide Stress Corrosion Cracking (SSCC) • Fatigue • Fretting at baffle plate to tube contact locations • Deposition leading to choking of tubes	Visual Check by Fibroscope/ Boroscope (VT), Hardness Checking, Eddy current testing (ECT)
6.	Process Pump casing	• Uniform Corrosion • Erosion-corrosion • Hydrogen Attack • Sulphide Stress Corrosion Cracking (SSCC) • Pitting Corrosion • Fatigue	Leak Survey, Visual Check (VT), Thickness Mapping, Hardness Mapping, Hydro testing

The ageing of critical rotary equipment & machineries are managed by periodic condition monitoring, surveillance and by preventive maintenance programme while the ageing of static equipment is monitored by various NDT techniques under periodic In-Service Inspection Programme.A code of Practice for In-Service Inspection Jobs of chemical based FCFs is developed. Based on this code, plant specific ISI manuals are prepared and followed in each plant.

The code of practice for In-Service Inspection includes: (a) Criteria for selection of SSCs (b) Responsibilities (c) Examination areas (d) Methods of NDE (e) Applicable codes and standards (f) Extent of examination (g) Examination Interval (h) Repair & Revalidation Criteria (i) Documentation (j) Quality Assurance & Audits.

SSCs of chemical based FCFs are classified based on severity of the effect of hazardous fluid release. Inspection of SSCs using different NDE methods is carried out at different stages as specified in approved QA Plans and ISI Program.

Various NDE methods (VT, PT, ECT, MPT, RT, UT, PAUT, TOFD etc.) are used during 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.

The ISI code of practice and the inspection results are reviewed by AERB for acceptability. Implementation of approved ISI program is verified during regulatory inspections carried out by AERB. Acceptability of NDE results obtained during ISI is important consideration in decision making process related to issuance/ renewal of regulatory consents.

So, programmes like Preventative maintenance, Surveillance, Condition Monitoring, In-Service Inspection, Fitness for Service etc. together helps in managing ageing of SSC during operation phase of the facility. However, the ageing management of SSCs has to be considered at each stage of the facility.

The chemical based FCFs also considered some ageing management measures right from site selection to operational phase. Some of the salient features adopted by the plant for ageing management are:

i. Location of the plant in thinly populated area with exclusion zone of 1.6 km during siting.
ii. Safe plant layout was considered like open installations, separation and adequate distance between hazardous and non-hazardous areas, predominant wind direction for location of control room, office buildings etc.
iii. Designing of SSCs considering influence of service conditions, transients etc.
iv. Positive tolerance has been provided on thickness of all the materials during designing.
v. Selection of compatible material at locations of high turbulence during designing.
vi. Selection of material with elaborate quality control procedures during fabrication.
vii. 100 % examinations of weld joints and pressure vessels during fabrication
viii. Plant is operated as per approved operation manuals and Technical Specification for Operation.
ix. Operation of plant by authorized manpower.

3.0 Regulatory Overview on Ageing Management Aspects in Chemical based Fuel Cycle Facilities:

Although chemical based FCFs has adopted various safety measures right from siting for managing ageing but this can be further improved by proper planning of ageing management of SSCs during different stages:

(a) Siting

i) The impact of new adjoining facilities shall be considered for life management.
ii) Protection from external natural events such as storms, cyclones, flooding, seismic etc.

(b) Design

i) Adequate provision for maintenance and replacement of equipment.
ii) Provision for In-Service Inspection
iii) Reliable performance during service life.

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 manufacturing processes

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

iii) Maintenance of appropriate conditions during erection of equipment.

(d) Commissioning

i) Collection of baseline data

ii) Pre-Service Inspection data

iii) Non-Conformance observations and corrective actions taken

(e) Operation

i) Monitoring Techniques:

- Condition Monitoring
- Surveillance
- Testing and periodic Inspection
- Data evaluation

ii) Mitigation Techniques:

- Maintenance
- Repair and Replacement
- Operating conditions and procedures

In spite of proper planning of ageing management during different stages of the plant, the following should be considered for effective ageing management of the SSCs:

a) Procurement, Manufacturing and Storage of Equipment:

The procured equipment/components should meet the design specification. The design specifications should cover technical and Quality Assurance (QA) requirements. Testing of materials used in fabrication shall be carried out in approved laboratories. The manufacturer should implement procedures for identifying material/components at receipt and all stages of manufacturing. Non-conformance should be documented, reviewed and approved by designer. Manufactured equipment should be tested as per specifications and stored in clean environment.

Appropriate procedures and storage conditions should be established and maintained for spares and subassemblies to prevent degradation. Procedure for storage of critical equipment 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.

b) **Personnel Training, Qualification & Certification**
The personnel performing ISI examination should be qualified and certified as per the requirements of applicable codes. The qualified NDE personnel should have adequate knowledge, skill and experience in respective NDE methods to be able to perform in a competent manner.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) **Equipment and Calibration Standards**
Equipment used for NDE examinations and tests should be of acceptable quality,range, performance characteristics and accuracy in accordance with applicablestandards. The calibration of the equipment together with the accessories should be carried out as stipulatedin governing codes/standards. The equipment should be properly identifiedwith calibration records. Validity of the calibrations should be verified regularlyin accordance with Quality Assurance (QA) programme.Reference blocks made to acceptable standards should be used for calibration.If such standards for calibration are not established, these blocks should be ofidentical material and surface finish and be subjected to the same fabrication(construction) conditions as the component being examined. The samereference blocks as used during manufacture and for PSI should be used forsubsequent ISI wherever practical.Reference specimen should contain discontinuities and conditions that arecomparable to existing or anticipated flaws or conditions. It should be used todemonstrate the ability of the inspection system when the calibrationspecimen is not adequate for detection or evaluation of such flaws.

d) **Construction and Erection Stage:**
Construction of plant equipment and components should be carried out as per approved procedures. Quality assurance (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 to be handed over to the commissioning group and for generation of baseline references, especially for in-situ fabricated equipment.

e) **Commissioning and Pre-Operational Data Collection:**
Baseline data during commissioning should be collected for comparison and trending during operation for detecting degradation due to ageing. In case, the baseline data is not available, then validated available data from first major turnaround can be considered for Pre–service Inspection.

f) **Monitoring and Mitigation of Ageing during Operation:**
Conditions of components based on the service condition, transients etc. should be monitored by appropriate technique to determine the degradation in safety margin of components. Monitoring of degradation or locating flaw in a component should be carried out by advanced non-destructive examination (NDE) technique like PAUT, TOFD, Internal rotary inspection system (IRIS) etc. and by online- monitoring technique like on-line fatigue monitoring of critical nozzles, vibration monitoring etc.For SSC important to safety, provisions should be made for locating test samples at specific areas. Post service examination for component gives information for managing important SSC.Data from condition monitoring, surveillance and In –Service Inspection (ISI) of selected SSCs 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 SSCs.

Appropriate data such as baseline data, operating history data and maintenance history data should be made available and maintained for selected SSCs for developing effective life management strategies for SSCs.

4. CONCLUSIONS

Foreffective implementation of ageing management programme for any chemical based FCFs, all site related parameters and other design related inputs which influence the life of SSC should be evaluated and accounted for in Siting, Design, Construction, Commissioning and Operation. Activities such as Site Selection, compilation of baseline data on environmental conditions, Design, Manufacturing, Storage, Construction, Commissioning and Operation have influence on safety and life span of SSC. Thus by taking appropriate measures as explained above at different stages of the plant, the ageing of a SSCs can be controlled. Even, use of advanced Monitoring techniques like PAUT, TOFD, online monitoring, standardized equipment & calibration instruments, qualified & certified NDT personnel, implementation of quality assurance plan during procurement, manufacturing, construction & erection, and suitable mitigation measures like controlling operating parameters, planning maintenance programme, modifications etc. during operation helps in effective ageing management of SSCs during operation.

References:

1] Life Management of Heavy Water Plants, October, 2014, Atomic Energy Regulatory Board
2] Life Management of Nuclear Power Plants, 2005, Atomic Energy Regulatory Board
3] Code of Practice for In Service Inspection of Heavy Water Plants (Rev.1), 2014,Atomic Energy Regulatory Board
4] In- Service Inspection of Nuclear Power Plants,March, 2004, Atomic Energy Regulatory Board