## AMP 125 BURIED and UNDERGROUND PIPING AND TANKS (VERSION 2021)

### Programme Description

This programme manages ageing of the external surfaces of buried and underground piping and tanks. The programme relies on recommendations for a comprehensive buried and underground piping and tanks programme [1] as delineated in pertinent governing requirements or guidance documents for the plant. It addresses piping and tanks composed of metallic, polymeric, cementitious, and concrete materials. This programme manages ageing through preventive actions and inspection activities and does not contain mitigating actions. It manages applicable ageing effects such as loss of material, cracking, and changes in material properties.

Buried piping and tanks are in direct contact with soil or concrete (e.g., a wall penetration). Underground piping and tanks are below grade but are contained within a tunnel or vault such that they are in contact with air and are located where access for inspection is restricted.

One example of an ageing management programme of buried and underground piping and tanks is provided in [2].

### Evaluation and Technical Basis

1. ***Scope of the ageing management programme based on understanding ageing:***

This programme manages ageing effects on the external surfaces of buried and underground piping and tanks constructed of metallic, polymeric, cementitious, and concrete materials. The programme addresses ageing effects such as loss of material, cracking, and changes in material properties.

This programme manages loss of material due to corrosion of piping system bolting within the scope of the long-term operation review. Other ageing effects associated with piping system bolting are managed through the use of AMP 115.

This programme does not manage selective leaching. The ageing effect of selective leaching of materials is addressed in AMP 120, which is applied in addition to this programme for applicable materials and environments.

This programme does not manage ageing effects on internal surfaces.

1. ***Preventive actions to minimize and control ageing degradation:***

a. Buried Piping and Tanks

Preventive actions utilized by this programme vary with the material of the tank or pipe and the environment (e.g., air, soil, concrete) to which it is exposed. These actions are external coating, cathodic protection and backfill quality. As an example, these actions are described in detail in [2].

Coatings are provided based on environmental conditions (e.g., stainless steel in chloride containing environments). Justification is provided when coatings are not provided. Coatings are in accordance with a consensus standard recognized by the national authorities. A broader range of coatings may be used if justification is provided.

Cathodic protection is in accordance with a consensus standard recognized by the national authorities. The system is operated so that the cathodic protection criteria and other considerations described in the standards are met at every location in the system. The equipment used to implement cathodic protection needs to be qualified in accordance with national regulations.

In case of not implementing the cathodic protection, it is demonstrated that such protection is either not required or not practical. The possibility is to use the criterion limit for effective corrosion control as it is stated in pertinent governing requirements or guidance documents. Demonstration that external corrosion rates are below limit is an acceptable basis for not implementing cathodic protection.

Backfill of the component is consistent with a consensus standard recognized by the national authorities. For materials other than aluminium, the use of controlled low strength materials (flowable backfill) is acceptable. Backfill quality may be demonstrated by plant records or by examining the backfill while conducting the inspections of this AMP. Backfill is acceptable if the inspections conducted of this AMP do not reveal evidence of mechanical damage to the component’s coatings, or the surface of the component if not coated, due to the backfill. For stainless steel and cementitious materials, backfill limits apply only if the component is coated [2].

1. Underground Piping and Tanks

Preventive actions utilized by this programme vary with the material of the underground tank or pipe and the environment to which it is exposed. External coating is the only preventive action identified for underground piping and tanks. As an example, these actions are described in detail in [2].

1. ***Detection of ageing effects:***

Loss of material is monitored by visual inspection of the exterior surface of the piping or tank and, in some instances, by measuring the wall thickness of the piping or tank. Wall thickness is determined by a non-destructive examination technique such as ultrasonic testing (UT).

Inspections for cracking are only implemented when the buried piping is excavated and direct visual examinations result in the removal of coatings for reasons other than to inspect for cracking. Inspections for cracking utilize a method that has been demonstrated to be capable of detecting cracking.

The pipe-to-soil potential and the cathodic protection current are monitored for piping and tanks in contact with soil and protected by a cathodic protection system in order to determine the effectiveness of cathodic protection systems and, thereby, the effectiveness of corrosion prevention.

Methods and frequencies used for the detection of ageing effects vary with the material and environment of the buried and underground piping and tanks. These methods and frequencies are outlined below.

a. Opportunistic Inspections

i. All buried and underground piping and tanks, regardless of their construction material, are inspected by visual means whenever they become accessible for any reason.

b. Directed Inspections – Buried Piping

i. Directed inspections for buried piping are conducted in accordance with national regulatory requirements, codes and standards.

ii. Inspection locations and periods are selected based on risk, considering both susceptibility to degradation and consequences of failure. Characteristics such as coating type, coating condition, cathodic protection efficacy, backfill characteristics, soil corrosivity (influenced by sulfides, chlorides content, pH, etc), pipe contents, and pipe function are considered. Piping systems that are backfilled using controlled low strength material generally experience lower corrosion rates and may be more difficult to excavate than piping systems backfilled using compacted aggregate fill. As a result, systems backfilled using aggregate fill are generally given a higher inspection priority than comparable systems that are completely backfilled using controlled low strength material.

iii. Visual inspections are supplemented with surface and/or volumetric non‑destructive testing (NDT) if significant indications are observed.

iv. Opportunistic examinations of non-leaking pipes may be credited toward these direct examinations if the location selection criteria are met.

v. Visual inspections for polymeric materials are augmented with manual examinations to detect hardening, softening, or other changes in material properties.

vi. The use of guided wave ultrasonic or other advanced inspection techniques is encouraged for the purpose of determining those piping locations that are inspected but may not be substituted for the inspections..

vii. Fire mains are inspected unless they are subjected to a flow test as described in a consensus standard recognized by the national authorities (e.g., NFPA‑25 [3]).

c. Directed Inspections – Underground Piping

i. Directed inspections for underground piping are conducted in accordance with national regulatory requirements, codes and standards.

ii. Inspection locations and periods are selected based on risk, considering both susceptibility to degradation and consequences of failure. Characteristics such as coating type, coating condition, external environment, pipe contents, and pipe function, are considered.

iii. Underground piping is inspected visually to detect external corrosion.

iv. Opportunistic examinations may be credited toward these direct examinations if the location selection criteria are met.

v. Visual inspections for polymeric materials are augmented with manual examinations to detect hardening, softening, or other changes in material properties.

vi. The use of guided wave ultrasonic or other advanced inspection techniques is encouraged for the purpose of determining those piping locations that are inspected but may not be substituted for the inspections.

vii. Fire mains are inspected unless they are subjected to a flow test as described in a consensus standard recognized by the national authorities (e.g., NFPA‑25 [3]).

d. Directed Inspections – Buried Tanks

i. Directed inspections for buried tanks are conducted in accordance with national regulatory requirements, codes and standards.

ii. Directed inspections will be conducted during each 10-year period beginning 10 years prior to the period of long-term operation.

iii. Examinations may be conducted from the external surface of the tank using visual techniques or from the internal surface of the tank using volumetric techniques. This area includes at least some of both the top and bottom of the tank. UT measurements are distributed uniformly over the surface of the tank. Double wall tanks may be examined by monitoring the annular space for leakage.

iv. Visual inspections for polymeric materials are augmented with manual examinations to detect hardening, softening, or other changes in material properties.

v. Opportunistic examinations may be credited toward these direct examinations.

e. Directed Inspections – Underground Tanks

i. Directed inspections for underground tanks are conducted in accordance with national regulatory requirements, codes and standards.

ii. Directed inspections will be conducted during each 10-year period beginning 10 years prior to the period of long-term operation.

iii. Examinations may be conducted from the external surface of the tank using visual techniques or from the internal surface of the tank using volumetric techniques. This area includes at least some of both the top and bottom of the tank. Double wall tanks may be examined by monitoring the annular space for leakage.

iv. Visual inspections for polymeric materials are augmented with manual examinations to detect hardening, softening, or other changes in material properties.

v. Opportunistic examinations may be credited toward these direct examinations.

f. Adverse Indications

i. Adverse indications observed during monitoring of cathodic protection systems or during inspections are entered into the plant corrective action programme. Adverse indications that are the result of inspections will result in an expansion of sample size. Examples of adverse indications resulting from inspections include leaks, material thickness less than minimum, coarse backfill of a coated piping or tank with accompanying coating degradation, and general or local degradation of coatings so as to expose the base material.

ii Adverse indications that fail to meet the acceptance criteria described in acceptance criteria will result in the repair or replacement of the affected component.

iii. If adverse indications are detected, inspection sample sizes within the affected piping categories are increased. If adverse indications are found in the expanded sample, an analysis is conducted to determine the extent of condition and extent of cause.

iv. If adverse conditions are extensive, inspections may be halted in a piping system, or portion of system that is planned for replacement. If the initial expansion of the sample size has not been conducted, or the determination of extent of condition or extent of cause requires further inspections, these inspections are conducted in locations with similar materials and environment.

g. Non – invasive diagnostic of the buried and underground piping

i. A variety of non-destructive evaluation (NDE) technologies exist capable of detecting and characterizing wall-loss damage and cracking in buried and underground piping [4]. Some of these technologies can be deployed on the inside of the pipe, without necessarily requiring excavation of the pipe. In-line deployment can be through a variety of means, such a robotic crawler, flow-through designs, or pulled-through and winched applications, among others. Selection of a given inspection technology considers aspects such as the pipe material type, damage mechanisms of concern, minimum flaw size that needs to be detected, pipe surface conditions and/or preparation requirements, among others. Mock-ups and demonstrations can be an effective means of assessing technology capabilities to meet the objectives of intended and planned inspections [5 ], [6], [7], [8].

ii. In-line inspections, referred to as PIG (pipeline inspection gauge) inspection techniques. In this technique, robotic crawlers are used to assess complex below ground piping systems. These crawlers include electromagnetic acoustic transducer (EMAT) ultrasonic testing sensors to measure pipe wall thickness and locate corrosion damage [9].

iii. The use of EDMET method for the measurement of mean residual wall thickness based on the measurement of electrical resistance together with reflectometry measuring an electric signal propagation speed between the conductor (pipe wall) and the insulator (dielectric, outer pipe insulation) [10].

iv. Non-contact magnetometric diagnostics of pipeline technical conditions based on the measurements of earth magnetic field distortion caused by the change of tube metal permeability in the stress concentration areas (corrosion, pipeline insulation damage, signals due to the influence of the electric cables or metal items fallen during pipeline laying, etc.) [11].

v. Ultrasonic examination by conventional and long range guided waves for detection of surface corrosion a coating protection degradation and magnetic flux leakage examination [12], [13], [14], [15]

vi. Resistive surge, geo scanner, concrete cover surges, corrosion potential (for reinforcement steel, for reinforced concrete and concrete) [16]

1. ***Monitoring and trending of ageing effects:***

For piping and tanks protected by cathodic protection systems, potential difference and current measurements are trended to identify changes in the effectiveness of the systems and/or coatings. If ageing of fire mains is managed through monitoring jockey pump activity (or similar parameter), the jockey pump activity (or similar parameter) is trended to identify changes in pump activity that may be the result of increased leakage from buried fire main piping. Where wall thickness measurements are conducted, the results are trended when follow up examinations are performed. Where any non-invasive diagnostic of the pipe condition is used, the resulting degradation development is trended.

1. ***Mitigating ageing effects:***

This programme does not contain any mitigating actions.

1. ***Acceptance criteria:***

The principal acceptance criteria associated with the inspections contained with this AMP are in accordance with pertinent governing requirements or guidance documents for the plant. Specific examples are provided in [2], including:

1. Criteria for soil-to-pipe potential when using a saturated copper/copper sulfate reference electrode -850 mV
2. For coated piping or tanks, there are either no evidence of coating degradation or the type and extent of coating degradation is insignificant as evaluated by an individual qualified in accordance with a consensus standard or training programme recognized by the national authorities (e.g., AMPP (Association for Materials Protection and Performance (former NACE), EPRI). Where damage to the coating has been evaluated as significant and the damage was caused by non-conforming backfill, an extent of condition evaluation is conducted to ensure that the as-left condition of backfill in the vicinity of observed damage will not lead to further degradation.

c. If coated or uncoated metallic piping or tanks show evidence of corrosion, the remaining wall thickness in the affected area is determined to ensure that the minimum wall thickness is maintained. This may include different values for large area minimum wall thickness, and local area wall thickness.

d. Cracking or blistering of nonmetallic piping is evaluated.

e. Cementitious or concrete piping may exhibit minor cracking and spalling provided there is no evidence of leakage or exposed rebar or reinforcing “hoop” bands.

f. Backfill is in accordance with specifications described, preventive actions to minimize and control ageing degradation.

g. Flow test results for fire mains are in accordance with a consensus standard recognized by the national authorities (e.g., NFPA‑25 [3]).

h. Changes in jockey pump activity (or similar parameter) that cannot be attributed to causes other than leakage from buried piping are not occurring.

i. The measured wall thickness projected to the end of the period of extended operation meets minimum wall thickness requirements.

j. Cracks in controlled low strength material backfill that could admit groundwater to the surface of the component are not acceptable.

1. ***Corrective actions:***

The site corrective actions programme, quality assurance (QA) procedures, site review and approval process, and administrative controls are implemented in accordance with the regulations imposed by the national authorities.

Measures are established to assure that conditions adverse to quality, such as failures, malfunctions, deficiencies, deviations, defective material and equipment, and nonconformances are promptly identified and corrected. In the case of significant conditions adverse to quality, the measures assure that the cause of the condition is determined and corrective action taken to preclude repetition. The identification of the significant condition adverse to quality, the cause of the condition, and the corrective action taken is documented and reported to appropriate levels of management.

1. ***Operating experience feedback and feedback of research and development results:***

This AMP addresses the industry-wide generic experience. Relevant plant-specific operating experience is considered in the development of the plant AMP to ensure the AMP is adequate for the plant. The plant implements a feedback process to periodically evaluate plant and industry-wide operating experience and research and development (R&D) results, and, as necessary, either modifies the plant AMP or takes additional actions (e.g. develop a new plant-specific AMP) to ensure the continued effectiveness of the ageing management.

Operating experience shows that buried and underground piping and tanks are subject to corrosion. Some examples of industry experience included in [2] may be of significance.

In 2014, a leak due to localized corrosion was observed on buried pipeline of the open cycle cooling water system. The root cause of integrity loss was violation of the piping backfill technology. The solution was the complex repair – replacement [17].

Below ground piping operating experience is summarised in CODAP database (Component Operational Experience, Degradation and Ageing Programme event database [18]. Some examples follow [9]:

In 1996 the sand buried fuel oil transfer pipe near the 345 kV switch yard was found to be leaking (BWR). After excavating, a dent and a pinhole was found at the surface of the pipe due to galvanic corrosion caused by stray current. The solution was replacement and recoating.

In 1996 during a hydraulic pressure test performed, a leak was found on a buried pipe containing radioactive waste water. The leakage was caused by local damage to the external bitumen coating and subsequent corrosion of the pipe. The affected pipe section was replaced.

The recommendation for nuclear power plants to implement and use ~~in implementing~~ an effective program to detect and mitigate degradation in buried piping systems is provided in [19].

In 2017-2018, contactless magnetometric diagnostics (based on the metal magnetic memory method) was applied at Kozloduy NPP (Bulgaria) to detect places with damaged insulation without excavating the pipelines. The method is based on the measurements of earth magnetic field distortion caused by the change of tube metal permeability in the stress concentration areas (corrosion, pipeline insulation damage, signals due to the influence of the electric cables or metal items fallen during pipeline laying, etc.). Examinations following procedure RD 102-008-2002 [20], developed under the Russian State Standards and methodology,  were carried out. Examination results showed mainly anomalies related to the signals caused by the influence of the electric cables, as well as places with metal items fallen during pipeline laying. The number of places with damaged insulation is insignificant. The results were checked after excavating areas with anomalies.

The programme includes provisions for continuing review of plant-specific and industry-wide operating experience, and research and development results, such that impact on the programme is evaluated and any necessary actions or modifications to the programme are performed.

Industry has developed some initiatives to manage buried and underground pipes and tanks [21].

The non – invasive diagnostic monitoring techniques ~~of non – invasive diagnostic~~ of the buried and underground piping used by this AMP are based on R&D activities performed by institutes, operators and member states active at the field of nuclear energy production.

1. ***Quality management:***

Site quality assurance procedures, review and approval processes, and administrative controls are implemented in accordance with the different national regulatory requirements (e.g., 10 CFR 50, Appendix B [22]).

**References**

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Buried and Underground Piping and Tank Ageing Management for Nuclear Power Plants, IAEA NE Series No. NP-T-3.20.

[2] UNITED STATES NUCLEAR REGULATORY COMMISSION, Generic Aging Lessons learned for Subsequent License Renewal (GAL-SLR) Report, NUREG-2191, “AMP XI.M41 Buried and Underground Piping and Tanks”, USNRC, 2015.

[3] NATIONAL FIRE PROTECTION ASSOCIATION (NFPA) Standard 25, Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems, 2008 edition.

[4] Nondestructive Evaluation: Buried Pipe NDE Reference Guide— Revision 3. EPRI, Palo Alto, CA: 2014. 3002004395

[5] Nondestructive Evaluation: Assessment and Development of Buried Pipe NDE Technology EPRI, Palo Alto, CA: 2013. 3002000463.

[6] Nondestructive Evaluation: Buried Pipe In-Line NDE Depth Sizing Procedure.EPRI, Palo Alto, CA: 2012.1025231

[7] Nondestructive Evaluation: Remote Field Technology Assessment for Piping Inspection, Including Buried and Limited Access Components. EPRI, Palo Alto, CA: 2010. 1021153.

[8] Nondestructive Evaluation: Assessment and Development of Buried Pipe NDE Technology, Revision 1. EPRI, Palo Alto, CA: 2017, 3002010027.

[9] Operating Experience Insight into Below Ground Piping at Nuclear Power Plants NEA/CSNI/R(2018)2, OECD, 2018.

[10] Methodology for non-destructive diagnostic and lifetime evaluation of non-accessible (buried and underground) piping, ABEGU, Krkonosská 358, Desna 468 61, 2015, Z/15/05/15

[11] Russian State Standards and Methodology for non-contact magnetometric diagnostic of operable heating lines, SO OAO MTK Moscow, 2009.

[12] Slovenian Technical Review Report on the Krsko NPP Ageing Management Program, Final Report, 2017.

[13] Development and Evaluation of Guided Wave Structural Health Monitoring for Buried Pipe. EPRI, Palo Alto, CA: 2016. 3002008032.

[14] Obtaining Credit for Guided Wave as a Buried Pipe Direct Examination. EPRI, Palo Alto, CA: 2013.3002000468.

[15] Buried Pipe Guided Wave Examination Reference Document. EPRI, Palo Alto, CA: 2009. 1019115.

[16] Topical Peer Review Ageing Management Swedish National Assessment Report, 2017, ISS: 2000-0456.

[17] Vincour, D., Krondak, M. “The status assessment of buried pipes”, 10th Conference of Lifetime Prolongation of Power Equipments, ISBN 978-80-261-0522-0, Srni, Czech Republic, October 20-22, 2015.

[18] NEA Component Operational Experience, Degradation and Ageing Programme (CODAP): Second Term (2015 – 2017) Status Report, NEA/CSNI/R(2019).

[19] Recommendations for an Effective Program to Control the Degradation of Buried and Underground Piping and Tanks (1016456, Revision 2). EPRI, Palo Alto, CA: 2020. 3002018352..

[20] РД 102-008-2002. Procedure for condition monitoring of the pipelines according to the contact free magnetic memory method (in Russian).

[21] NEI 09-14 “Guideline for the management of underground piping and tank integrity”, Rev 3, April 2013.

[22] UNITED STATES NUCLEAR REGULATORY COMMISSION 10 CFR Part 50, Appendix B, Quality Assurance Criteria for Nuclear Power Plants, Office of the Federal Register, National Archives and Records Administration, USNRC, Latest Edition.