XI.M41 BURIED AND UNDERGROUND PIPING AND TANKS

Program Description

This is a comprehensive program designed to manage the aging of the external surfaces of buried and underground piping and tanks. It addresses piping and tanks composed of any material, including metallic, polymeric and cementitious materials. This program manages aging through preventive, mitigative and inspection activities. It manages all applicable aging effects such as loss of material, cracking, and changes in material properties.

Depending on the material, preventive and mitigative techniques include: the material itself, corrosion resistant coatings, and the application of cathodic protection. Also, depending on the material, inspection activities include electrochemical verification of the effectiveness of cathodic protection, non-destructive evaluation of pipe or tank wall thicknesses, and visual inspections of the pipe or tank from the exterior as permitted by opportunistic or directed excavations.

Although this program considers the fluid inside the pipe or tank, and certain aspects of the program may be carried out from the inside of the pipe or tank, this program is designed to address only the degradation occurring on the outside of the pipe or tank. Aging of the inside of the pipe or tank is managed by another program (e.g. Open Cycle Cooling Water (AMP XI.M20), Treated Water (XIM.21A), Internal Inspection of Miscellaneous Piping and Ducts XI.MXX) or Water Chemistry (XI.M2). Additionally, this program does not address selective leaching. The selective leaching program (Chapter XI.M33) is applied in addition to this program for applicable materials and environments.

The terms "buried and underground are fully defined in Chapter IX of the GALL Report. Briefly, 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.

Evaluation and Technical Basis

1. ***Scope of Program***: This program is used to manage the effects of aging for buried and underground piping and tanks constructed of any material including metallic, polymeric and cementitious materials. The program addresses aging effects such as loss of material, cracking, and changes in material properties. Any system may contain buried and underground piping or tanks. Typical systems include service water piping and components, condensate storage transfer lines, fuel oil and lubricating oil lines, fire protection piping and piping components (fire hydrants), and storage tanks. The aging of bolting associated with piping systems within the scope of this program is also managed by this program.

2. ***Preventive Actions:*** Preventive actions utilized by this program vary with the material of the tank or pipe and the environment (air, soil, or concrete) to which it is exposed. These actions are outlined below

   a. Preventive Actions, Buried Piping and Tanks

      i. Preventive actions for buried piping and tanks are conducted in accordance with Table 2a and its accompanying footnotes

Table 2a, Preventive Actions for **Buried** Piping and Tanks

Material[1]	Coating[2]			Cathodic Protection[4]	Backfill		
	None Reqd.	May be Reqd.[3]	Reqd.		No Limit[5]	High Quality[6]	Fine[7]
Titanium	X				X		
Super Austenitic Stainless[9]	X				X		
Stainless Steel		X				X[8]	
Steel			X	X		X	
Copper			X	X		X	
Aluminum			X	X		X	
Cement		X				X[8]	
Polymer	X						X

1. Materials classifications are meant to be broadly interpreted; e.g. all alloys of titanium which are commonly used for buried piping are to be included in the titanium category. Steel is as defined in chapter IX of this report. Polymer includes polymeric materials as well as composite materials such as fiberglass

2. When provided, coatings are in accordance with NACE SP0169-2007 or RP0285-2002.

3. Requirement for coating depends on environmental conditions. If coatings are not provided, a justification is provided in the LRA

4. Cathodic protection is in accordance with NACE SP0169-2007 or RP0285-2002. Attempts to demonstrate that cathodic protection is not required as discussed in Sections 1.2 and 3 of SP0169-2007 will not be considered.

5. No limits are placed on backfill quality

6. Backfill is consistent with 49 CFR 195.252. Maximum size of aggregate or other material within 6 inches of pipe is ½ inch in diameter or less.

7. Particle size for backfill within 6 inches of the pipe must not exceed that of sand grains

8. Backfill limits apply only if piping is coated.

9. e.g. Al6XN or 254 SMO

b. Preventive Actions, Underground Piping and Tanks

   i. Preventive actions for underground piping and tanks are conducted in accordance with Table 2b and its accompanying footnotes

Table 2b, Preventive Actions for **Underground** Piping and Tanks

Material[1]	Coating[2]		
	None Reqd.	May be Reqd.[3]	Reqd.
Titanium	X		
Super Austenitic Stainless[4]	X		
Stainless Steel		X	
Steel			X
Copper	X		
Aluminum		X	
Cement			
Polymer	X		

1. Materials classifications are meant to be broadly interpreted; e.g. all alloys of titanium which are commonly used for buried piping are to be included in the titanium category. Steel is as defined in chapter IX of this report. Polymer includes polymeric materials as well as composite materials such as fiberglass

2. When provided, coatings are in accordance with NACE SP0169-2007 or RP0285-2002. A broader range of coatings may be used if justification is provided in the LRA.

3. Requirement for coating depends on environmental conditions. If coatings are not provided, a justification is provided in the LRA

4. e.g. Al6XN or 254 SMO

3. ***Parameters Monitored/Inspected:*** The aging effects addressed by this AMP are loss of material due to all forms of corrosion and, potentially, cracking due to stress corrosion cracking. Two parameters are monitored to detect and manage these aging effects: visual appearance of the exterior of the piping or tank; and wall thickness of the piping or tank, generally as determined by a non-destructive examination technique such as ultrasonic testing (UT). Two additional parameters, the pipe-to-soil potential and the cathodic protection current, are monitored to determine the effectiveness of cathodic protection systems and, thereby, the effectiveness of corrosion mitigation.

4. ***Detection of Aging Effects:*** Methods and frequencies used for the detection of aging 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 material of construction are opportunistically inspected by visual means whenever they become accessible for any reason.

b. Directed Inspections – Buried Pipe

i. Directed inspections for buried piping are conducted in accordance with Table 4a and its accompanying footnotes

ii. Directed inspections as indicated in Table 4a will be conducted during each 10 year period beginning 10 years prior to the entry into the period of extended operation.

iii. Inspection locations are selected based on susceptibility to degradation. Issues such as coating type, coating condition, cathodic protection efficacy, backfill characteristics and soil resistivity are considered

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

v. Opportunistic examinations may be credited toward these direct examinations if the location selection criteria in iii, above, are met

vi. At multi-unit sites, individual inspections of shared piping may not be credited for more than one unit.

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

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

Table 4a, Inspections of **Buried Pipe**

Material	CP Survey[1]	Visual Inspections[2]			Minimum Inspections[5]
		ASME Code Class Pipe	Haz Mat Pipe[3]	Other Pipe[4]	
Titanium					
Super Austenitic Stainless[10]					
Stainless Steel		2%	2%	1%	1
Steel	X	10%[6]	5%[6]	1%[6]	2
Copper	X	2%[6]	2%[6]	1%[6]	1
Aluminum	X	5%[6]	2%[6]	1%[6]	1
Cement		N/A[7]	N/A[7]	1%	1
HDPE[8]		1%[11]	1%[11]		1
Other Polymer[9]		2%	2%	1%	1

1. Cathodic protection survey in accordance with NACE SP0169-2007

2. Numerical values under the visual inspection heading indicate the percentage in linear feet of piping of the category indicated which is to be excavated and visually inspected,

i.e., if stainless steel piping is present in each of the three categories of piping a minimum of 3 excavations are required, one for each piping category. One or more excavations are conducted to inspect at least 2% of the code class piping; one or more excavations are conducted to inspect at least 2% of the Haz Mat piping; and one or more excavations are conducted to inspect at least 1% of the "other" piping. **Alternatively**, the entire length of stainless steel piping present in all three piping categories may be considered to be code class piping and inspected accordingly, i.e., one or more excavations are conducted to inspect at least 2% of the total length of stainless steel piping present.

3. Haz Mat pipe is pipe which, during normal operation, contains water contaminated with radioisotopes at levels greater than background or fluids other than water which, if released, would be detrimental to the environment e.g., diesel fuel.

4. Other pipe is pipe which is not code class pipe and which, during normal operations, contains only water which is not contaminated with radioisotopes at levels in excess of background.

5. Minimum inspections identify the minimum number of separate excavations which are required for each piping material. The minimum length for each excavation is 10 feet

6. Inspection of the prescribed length of piping may be eliminated when the installed cathodic protection system has been operating in accordance with NACE SP0169-2007 for 90% of the time since the pipe was originally installed or was visually inspected. The prescribed minimum number of visual inspections must still be met. Visual inspection as used here means visually inspecting a length of pipe equal to the amount indicated in the table, i.e., in order to eliminate the requirement to inspect 10% of buried steel code class piping, the installed cathodic protections system must have operated 90% of the time since that piping was installed or since 10% of it was visually inspected.

7. The use of cement piping in ASME code class and Haz Mat applications is not expected. If cement piping is used in these applications an inspection program is to be provided and justified in the LRA

8. HDPE pipe includes only HDPE pipe approved for use by the NRC for buried applications

9. Other polymer piping includes some HDPE pipe, and all other polymeric materials including composite materials such as fiberglass

10. e.g. Al6XN or 254 SMO

11. Refers to the percentage of welds (not linear length of pipe) which must be inspected. These inspections may be omitted if the pipe was volumetrically inspected when installed and no indications were noted and if the operating temperature of the pipe does not exceed 100° F

c. Directed Inspections – Underground Pipe

   i. Directed inspections for Underground piping are conducted in accordance with Table 4b and its accompanying footnotes

ii. Directed inspections as indicated in Table 4b will be conducted during each 10 year period beginning 10 years prior to the entry into the period of extended operation

iii. Inspection locations are selected based on susceptibility to degradation. Issues such as coating type, coating condition, exact external environment, and flow characteristics within the pipe, are considered

iv. Underground pipes are inspected visually to detect external corrosion and by UT to detect internal corrosion.

v. Opportunistic examinations may be credited toward these direct examinations if the location selection criteria in iii, above are met

vi. At multi-unit sites, individual inspections of shared piping may not be credited for more than one unit.

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

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

Table 4b, Inspections of **Underground Pipe**

Material	Visual and UT Inspections[1]			Minimum Inspections[4]
	ASME Code Class Pipe	Haz Mat Pipe[2]	Other Pipe[3]	
Titanium				
Super Austenitic Stainless[7]				
Stainless Steel	2%	2%	1%	1
Steel	10%	5%	1%	2
Copper	2%	2%	1%	1
Aluminum	5%	2%	1%	1
Cement	N/A[5]	N/A[5]	NA[5]	1
Polymer[6]	2%	2%	1%	1

1. Numerical values under the visual inspection heading indicate the percentage in linear feet of piping of the category indicated which is to be inspected using visual and ultrasonic techniques, i.e., if stainless steel piping is present in each of the three categories of piping a minimum of 3 inspections are conducted, one for each piping category. One or more inspections are conducted to inspect at least 2% of the code class piping; one or more inspections are conducted to inspect at least 2% of the Haz Mat piping; and one or more inspections are conducted to inspect at least 1% of the "other" piping. **Alternatively**, the entire length of stainless steel piping present in all three piping categories may be considered to be code class piping and inspected accordingly, i.e., one or more inspections are conducted to inspect at least 2% of the

total length of stainless steel piping present. All piping which is visually inspected to detect external corrosion is ultrasonically inspected to detect internal corrosion. UT inspection intervals will not exceed one foot. Particular attention is paid to elbows and the adjacent piping.

2. Haz Mat pipe is pipe which, during normal operation, contains water contaminated with radioisotopes at levels greater than background or fluids other than water which, if released, would be detrimental to the environment, e.g., diesel fuel.

3. Other pipe is pipe which is not code class pipe and which, during normal operations, contains only water which is not contaminated with radioisotopes at levels in excess of background.

4. Minimum inspections identify the minimum number of separate inspection locations which are required for each piping material. The minimum length for each inspection is 10 feet

5. The use of cement piping in ASME code class and Haz Mat applications is not expected. If cement piping is used in these applications an inspection program is to be provided and justified in the LRA

6. All polymeric materials including composite materials such as fiberglass. No distinction is drawn for underground piping between high density polyethylene approved for use by the NRC in buried applications and other polymeric piping materials.

7. e.g. Al6XN or 254 SMO

d. Directed Inspections – Buried Tanks

   i. Directed inspections for buried tanks are conducted in accordance with Table 4c and its accompanying footnotes

   ii. Directed inspections as indicated in Table 4c will be conducted during each 10 year period beginning 10 years prior to the entry into the period of extended operation

   iii. Each buried tank constructed from a material for which an examination requirement is contained in Table 4c is examined

   iv. Cathodic protection surveys are in accordance with NACE RP0285-2002

   v. 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. If the tank is inspected from the external surface a minimum 25% coverage is required. This area must include at least some of both the top and bottom of the tank. If the tank is inspected internally by UT, at least 1 measurement is required per square foot of tank surface. If the tank is inspected internally by another volumetric technique, at least 90% of the surface of the tank must be inspected

   vi. Tanks that cannot be examined using volumetric examination techniques are examined visually from the outside

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

viii. Opportunistic examinations may be credited toward these direct examinations

Table 4c, Inspections of **Buried Tanks**

Material	CP Survey	Visual/Volumetric Inspection
Titanium		
Super Austenitic Stainless[3]		
Stainless Steel		X
Steel	X	X
Copper	X	X
Aluminum	X	X
Polymers[1, 2]		X

1. All polymeric materials including composite materials such as fiberglass. No distinction is drawn for underground piping between high density polyethylene approved for use by the NRC in buried applications and other polymeric piping materials.

2. Volumetric Inspection not required for polymeric materials

3. e.g. Al6XN or 254 SMO

e. Directed Inspections – Underground Tanks

i. Directed inspections for underground tanks are conducted in accordance with Table 4d and its accompanying footnotes

ii. Directed inspections as indicated in Table 4d will be conducted during each 10 year period beginning 10 years prior to the entry into the period of extended operation

iii. Each underground tank constructed from a material for which an examination requirement is contained in Table 4d is examined

iv. 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. If the tank is inspected from the external surface a minimum 25% coverage is required. This area must include at least some of both the top and bottom of the tank. If the tank is inspected internally by UT, at least 1 measurement is required per square foot of tank surface. If the tank is inspected internally by another volumetric technique, at least 90% of the surface of the tank must be inspected

v. Tanks that cannot be examined using volumetric examination techniques are examined visually from the outside

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

vii. Opportunistic examinations may be credited toward these direct examinations

Table 4d, Inspections of **Underground Tanks**

Material	Visual/Volumetric Inspection
Titanium	
Super Austenitic Stainless[3]	
Stainless Steel	X
Steel	X
Copper	X
Aluminum	X
Polymers[1, 2]	X

1. All polymeric materials including composite materials such as fiberglass. No distinction is drawn for underground piping between high density polyethylene approved for use by the NRC in buried applications and other polymeric piping materials.

2. Volumetric Inspection not required for polymeric materials

3. e.g. Al6XN or 254 SMO

f. Adverse findings

i. Adverse indications observed during monitoring of cathodic protection systems or during inspections are entered into the plant corrective action program. Adverse indications will result in an expansion of sample size. At a minimum, leaks, material thickness less than minimum, the presence of coarse backfill within 6 inches of a coated pipe or tank (see Table 2A Footnote 6), and general or local degradation of coatings so as to expose the base material are considered adverse indications.

ii Adverse indications which fail to meet the acceptance criteria described in element 6 below, will result in the repair or replacement of the affected component

iii. An analysis may be conducted to determine the potential extent of the degradation observed. Expansion of sample size may be limited by the extent of piping or tanks subject to the observed degradation mechanism

iv. If adverse indications are detected, sample sizes within the affected piping categories are doubled. If adverse indications are found in the expanded sample, the sample size is again doubled. This doubling of sample size continues as necessary.

5. ***Monitoring and Trending:*** 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. Numerical measurements obtained from any

inspections are trended to monitor corrosion rates and estimate the remaining life of piping and tanks.

6. ***Acceptance Criteria:*** The principal acceptance associated with the inspection contained with this AMP follow:

   a. Criteria for soil-to-pipe potential are listed in NACE Standards RP0285-2002 and SP0169-2007.

   b. For coated piping or tanks, there should be no evidence of coating 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. 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 in element 4 (above) of this AMP.

7. ***Corrective Actions:*** The site corrective actions program, quality assurance (QA) procedures, site review and approval process, and administrative controls are implemented in accordance with the requirements of 10 CFR Part 50, Appendix B. The staff finds the requirements of 10 CFR Part 50, Appendix B, acceptable to address the corrective actions, confirmation process, and administrative controls.

8. ***Confirmation Process:*** The confirmation process ensures that preventive actions are adequate to manage the aging effects and that appropriate corrective actions have been completed and are effective. The confirmation process for this program is implemented through the site's QA program in accordance with the requirements of 10 CFR Part 50, Appendix B.

9. ***Administrative Controls:*** The administrative controls for this program provide for a formal review and approval of corrective actions. The administrative controls for this program are implemented through the site's QA program in accordance with the requirements of 10 CFR Part 50, Appendix B.

10. ***Operating Experience:*** Operating experience shows that buried and underground piping and tanks are subject to corrosion. Corrosion of buried oil, gas, and hazardous materials pipelines have been adequately managed through a combination of inspections and mitigative techniques, such as those prescribed in NACE SP0169-2007 and NACE RP0285-2002. Given the differences in piping and tank configurations between transmission pipelines and those in nuclear facilities, it is necessary for applicants to evaluate both plant-specific and nuclear industry operating experience and modify its aging management program accordingly. The following industry experience may be of significance to an applicant's program:

a. On February 21, 2005, a leak was detected in a 4-inch condensate storage supply line. The cause of the leak was microbiologically influenced corrosion or under deposit corrosion. The leak was repaired in accordance with the American Society of Mechanical Engineers (ASME) Section XI, "Repair/Replacement Plan".

b. On September 6, 2005, a service water leak was discovered in a buried service water header. The header had been in service for 38 years. The cause of the leak was either failure of the external coating or damage caused by improper backfill. The service water header was relocated above ground.

c. In October 2007, degradation of essential service water piping was reported. This led to an NRC special inspection in February 2008. The Institute of Nuclear Power Operations issued a significant operating event report discussing the degradation of the essential service water piping and concluded the degradation was caused by exposure to extreme conditions (including being buried).

d. On August 19, 2008, a flexible PVC pipe ruptured in the service water system. The rupture was related to Tropical Storm Fay, which washed away the soil where the piping was buried and washed additional soil away beneath the piping. This caused the PVC piping to sag and break free at the connecting joints. This section of piping was repaired.

e. In February 2009, a leak was discovered on the return line to a CST

f. In April 2009, a leak was discovered in an aluminum pipe where it went through a concrete wall. The piping was for the condensate transfer system. The failure was caused by vibration of the pipe within its steel support system. This vibration led to coating failure and eventual galvanic corrosion between the aluminum pipe and the steel supports.

g. In May 2009, diesel/fuel oil odor was identified in the ground water near the diesel generator building. The area was excavated to find the source of the leak.

h. In June 2009, an active leak was discovered in underground piping associated with a condensate storage tank (CST). The leak was discovered because elevated levels of tritium were detected. There were similar leaks in buried piping in 2004 and 2006, and those sections of piping were replaced.

References

10 CFR Part 50, Appendix B, *Quality Assurance Criteria for Nuclear Power Plants*, Office of the Federal Register, National Archives and Records Administration, 2009.

NACE Standard SP0169-2007, *Control of External Corrosion on Underground or Submerged Metallic Piping Systems*, 2007.

NACE Standard RP0285-2002, *Standard Recommended Practice Corrosion Control of Underground Storage Tank Systems by Cathodic Protection,* revised April 2002.