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This Technical Committee Report has been prepared by NACE International Task Group (TG) 404, "Nuclear Buried Piping."*

State-of-the-Art Report: External Corrosion, Assessment, and Control of Buried Piping Systems in Nuclear Power Plants

Foreword

Recent operating experience from nuclear power plants, particularly those located in the United States, many of which are between 30 and 40 years old, indicates that degradation of buried piping is occurring in at least some plants and represents an issue requiring the attention of the nuclear industry. Degradation in a variety of forms has been observed on both the external and internal surfaces of the pipe. In most cases to date, the degradation was not detected until a leak was identified. Some of these leaks have resulted in the release of radioisotopes (normally tritium) and materials that may be harmful to the environment (hereafter, "environmentally sensitive material"). These events (a) have not resulted in the loss of the intended safety function of any component or system; (b) have not resulted in off-site exposure to radiation in excess of regulatory limits; (c) constitute only about 10% of the leaks of tritium containing water into the environment; and (d) have attracted significant public attention.

It is the intent of this NACE International technical committee report to provide an overview of issues associated with buried piping that might be applicable worldwide. This report, however, is written from the perspective of experiences in the United States. This approach was taken primarily because of a lack of publicly available international information concerning this topic.

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This report addresses a subset of the operating experience described above. It includes only topics related to the external corrosion of buried piping, i.e., piping that is in direct contact with soil or concrete. It does not include topics related to internal corrosion of buried piping. Additionally, it does not include topics related to the corrosion of buried tanks, such as those in contact with soil, concrete, or underground piping and tanks, i.e., those enclosed in a vault or trench.

As with all NACE state-of-the-art reports, it is not the intent of this report to be a complete treatise on the subject of degradation, corrosion prevention, or corrosion mitigation of buried piping. Rather, it is the intent of this report to identify issues for corrosion professionals to consider when addressing degradation of buried piping in nuclear power plants. The report introduces subjects and identifies applicable reference material on the subject. When a specific issue related to buried piping degradation is found to be unique to nuclear power plants, and when ample reference material is not available, this report provides additional text concerning the issue. The length of the sections of this report correlate with the uniqueness, not the importance, of the topic considered with respect to buried piping at nuclear power plants.

This state-of-the-art technical committee report was prepared by NACE Task Group (TG) 404, “Nuclear Buried Piping.” TG 404 is administered by Specific Technology Group (STG) 41, “Electric Utility Generation, Transmission, and Distribution.” It is sponsored by STG 03, “Coatings and Linings, Protective—Immersion and Buried Service”; STG 05, “Cathodic/Anodic Protection”; and STG 35, “Pipelines, Tanks, and Well Casings.” This technical committee report is issued by NACE under the auspices of STG 41.

> NACE technical committee reports are intended to convey technical information or state-of-the-art knowledge regarding corrosion. In many cases, they discuss specific applications of corrosion mitigation technology, whether considered successful or not. Statements used to convey this information are factual and are provided to the reader as input and guidance for consideration when applying this technology in the future. However, these statements are not intended to be recommendations for general application of this technology, and must not be construed as such.

Table of Contents

Introduction

Recent operating experience from nuclear power plants, particularly those located in the United States, many of which are between 30 and 40 years old, indicates that degradation of buried piping is occurring in at least some plants and represents an issue requiring the attention of the nuclear industry. Degradation in a variety of forms has been observed on both the external and internal surfaces of the pipe. In most cases to date, the degradation was not detected until a leak was identified. Some of these leaks have resulted in the release of radioisotopes (normally tritium) and materials that may be harmful to the environment (environmentally sensitive material). These events:

(a) have not resulted in the loss of the intended safety function of any component or system;

(b) have not resulted in off-site exposure to radiation in excess of regulatory limits;

(c) constitute only about 10% of the leaks of tritium containing water into the environment;[1] and

(d) have attracted significant public attention.[1]

Buried piping in nuclear power plants includes safety-related piping (required to attain or maintain plant shutdown), generally ASME International (ASME)[(1)] Class 3, and nonsafety-related piping. Although the number of piping systems that are wholly or partially buried varies from plant to plant, more than 30 different systems have been identified as being at least partially buried at several plants.

Typical systems that are at least partially buried include service water (generally raw water used to cool safety and nonsafety-related components), fuel oil, lube oil, compressed air, circulating water, and fire protection. Additionally, other systems that carry gases, such as oxygen, hydrogen, and nitrogen, may be buried.

The following is a list of events from the U.S. Nuclear Regulatory Commission (NRC)[(2)] NUREG-1801, Generic Aging Lessons Learned (GALL) Report Revision 2, Aging Management Program (AMP) XI.M41,[2] that provides some indication of the range of recent occurrences.

(a) In February 2005, a leak was detected in a 4 in (102 mm) condensate storage supply line. The cause of the leak was microbiologically influenced corrosion (MIC) or under-deposit corrosion. The leak was repaired in accordance with the ASME Boiler & Pressure Vessel Code (BPVC), Section XI, "Inservice Inspection of Nuclear Power Plant Components."[3]

(b) In September 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 February 2009, a leak was discovered on the return line to a condensate storage tank. The cause of the leak was coating degradation, probably as a result of the installation specification not containing restrictions on the type of backfill, allowing rocks in the backfill. The leaking piping was also located close to the water table.

(d) In June 2009, an active leak was discovered in buried piping associated with a condensate storage tank. The leak was discovered because elevated levels of tritium were detected. The cause of the through-wall leaks was determined to be the degradation of the protective moisture barrier wrap that allowed moisture to come in contact with the piping, resulting in external corrosion.

A similar list of events from international nuclear power plants is not available. Based on a lack of international information, this report has been written from the perspective of power plants located in the United States but may be viewed in an international context.

Definitions for Underground and Buried Piping

In general, terms used in this report either carry their common meaning or are defined at their point of usage. The definitions of many of the corrosion-related terms used in this report can be found in NACE/ASTM[(3)] G193.[4] The terms "buried piping" and "underground piping" are addressed here as these terms are defined by the U.S. Nuclear Regulatory Commission (NRC) and, in

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[(1)] ASME International (ASME), Three Park Ave., New York, NY 10016-5990.
[(2)] U.S. Nuclear Regulatory Commission (NRC), Washington, DC 20555-0001.
[(3)] ASTM International (ASTM), 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959.

two slightly different ways, by Nuclear Energy Institute(4) (NEI) in NEI 09-14 Rev. 2, "Guideline for the Management of Underground Piping and Tank Integrity."[5] These definitions, while superficially similar, are not fully consistent.

Buried Piping (NRC GALL Report section IX.D)—Buried piping is piping that is in direct contact with soil or concrete (e.g., a wall penetration).

Buried Piping (NEI 09-14 Rev. 2) (Definitions section)—Piping that is below grade and in direct contact with the soil.

Buried Piping (NEI 09-14 Rev. 2) (Scope section)—All piping that is below grade and contains any fluid and is in direct contact with the soil.

Underground Piping (NRC GALL Report section IX.D)—Underground piping is piping that is below grade, but is contained within a tunnel or vault such that it is in contact with air and is located where access for inspection is restricted.

Underground Piping (NEI 09-14 Rev. 2) (Definitions section)—All piping that is below grade, not accessible, and outside of buildings. Buried piping (below grade and in direct contact with the soil) is considered to be a subset of underground piping.

Underground Pipe (NEI 09-14 Rev. 2) (Scope section)—Underground piping and tanks that are outside of a building and below grade (whether or not they are in direct contact with the soil) if they are safety-related or contain licensed material or are known to be contaminated with licensed material.

Each of these definitions is appropriate for the manner in which it is used in its parent document; for the remainder of this report, the NRC GALL Report buried pipe definition is used unless otherwise specified.

Recent Nuclear Buried Piping Activities and Publications

Significant actions in response to the degradation of buried piping have been taken by the NRC and the nuclear industry, primarily the NEI and the Electric Power Research Institute (EPRI).(5) These actions are described in the paragraphs below.

The NRC's actions have been focused on plants that have or will be applying for a renewed operating license as permitted by the NRC, Title 10, Code of Federal Regulations (CFR) 54.31.[6] This authority is subject to paragraphs 10 CFR 54.29; 10 CFR 54.21(a)(1); and 10 CFR 54.4.[6] In combination, these paragraphs of the CFR permit the extension of an original 40 year license for a nuclear power plant by 20 years provided the aging of passive long-lived components is adequately managed.

In an effort to assist licensees in preparing applications for license renewal consistent with the objectives of the regulations and provide consistency in the review of those applications, the NRC developed, and periodically revises, the GALL Report. The GALL Report addresses specific degradation effects that occur in components constructed from typical materials exposed to environments that typically occur in nuclear power plants.

Additionally, the GALL Report contains Aging Management Programs (AMPs). These programs have been found to be suitable by the NRC for managing the effects of aging of components under consideration. The latest revision of the GALL Report, Rev. 2, was published in December 2010.

As part of Revision 2 to the GALL Report, the NRC reviewed the existing AMPs related to buried piping (GALL Rev. 1[7] AMPs XI.M28, Buried Piping and Tanks Surveillance, and XI.M34, Buried Piping and Tanks Inspection) and found them to be less than ideal approaches to the management of buried piping given the available operating experience. The revised AMP (GALL Rev. 2 XI.M41, Buried and Underground Piping and Tanks) emphasizes the use of preventive and mitigative actions (corrosion-resistant piping, coatings, and cathodic protection [CP]) and bases the number of inspections to be conducted on the significance of the pipe, the material of construction of the pipe, and the environment surrounding the pipe.

The U.S. nuclear industry has taken several actions related to the degradation of buried piping. These actions began in 2007. Unlike the action taken by the NRC, which is primarily directed toward license renewal, actions taken by the nuclear industry resulted in initiatives that are not mandated by regulation, i.e., are voluntary relative to the NRC, but which are mandatory within the U.S. nuclear industry. These actions are summarized as follows:

(a) In May 2007, EPRI conducted a Nuclear Power Plants Piping Integrity Workshop in which integrity of buried pipe was identified as one of the top priorities.

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(4) Nuclear Energy Institute (NEI), 1776 I Street NW, Suite 400, Washington, DC 20006-3708.
(5) Electric Power Research Institute (EPRI), 3420 Hillview Ave., Palo Alto, CA 94304.