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Cathodic Protection Systems for the Mitigation of External Corrosion of Buried and Submerged Metallic Piping Systems at Nuclear Power Plants

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ABSTRACT

This standard presents accepted methods and practices regarding the use of cathodic protection (CP) for the control of external corrosion on buried or submerged carbon steel, stainless steel, gray cast iron, ductile cast iron, copper, and aluminum piping systems at nuclear power plants. This standard may be useful at facilities other than nuclear power plants that contain complex networks of buried or submerged piping, which may be composed of more than one material and may or may not be grounded.

This standard addresses the design of CP systems in nuclear power plants for new piping systems and existing coated and uncoated piping systems. For each type of system, information is provided concerning the effects of grounding of the piping system on the design of the CP system. It also introduces design concepts for new piping systems that will assist in the design, operation, testing, or maintenance of a CP system.

This standard also presents accepted methods and practices for the installation, operation (including acceptance criteria), testing, and maintenance of CP systems in nuclear power plants. It presents criteria and procedures that may be used to determine the conditions under which a pipe or piping system need not be cathodically protected.

KEYWORDS

Cathodic protection, nuclear power, ICCP, GACP, piping, TG 491.

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Foreword

The primary NACE standard addressing cathodic protection (CP) of buried and submerged onshore piping systems is SP0169, "Control of External Corrosion on Underground or Submerged Metallic Piping Systems."[1] While the scope of SP0169 is primarily intended for onshore buried and submerged metallic piping systems, its major users include the oil and gas industry. Oil and gas transmission pipelines share certain characteristics which affect the design, installation, operation, and maintenance of CP systems.

Oil and gas transmission and distribution pipelines typically are constructed from carbon steel for reasons of cost, strength, and ease of fabrication. Since carbon steel has a relatively low resistance to corrosion when buried in soil, the pipeline industry relies on coatings and CP to provide external corrosion control. The pipeline industry also uses a variety of aboveground assessment methods (e.g., in the United States, 49 CFR Part 192.921[2] and 49 CFR Part 195.452[j])[2] that are generally based on potential, electromagnetic, or current flow measurements in conjunction with inline inspections, hydrostatic testing, and excavations to verify the effectiveness of coatings and CP systems, and the integrity of the pipe for continued service. As a result of the relative simplicity of transmission pipeline systems, (i.e., long, straight, electrically isolated runs of pipe with a few structures nearby), the industry has been highly successful in developing coating and CP systems that adequately protect the piping without adversely affecting the coating system. Again, because of the relative simplicity of the piping system configurations, the transmission pipeline industry also has been highly effective in developing inspection methodologies to detect and assess degradation that may be occurring.

While SP0169 is technically applicable to buried and submerged piping systems at nuclear power plants, piping systems at these plants differ substantially from oil and gas transmission pipelines. Some of these differences include:

a) Transmission pipelines typically consist of very long lengths of pipe; while pipe lengths at nuclear power plants are typically much shorter. Due, in part, to the length of transmission pipelines, cathodically protected carbon steel pipe universally provides lower life cycle costs than other, more corrosion resistant materials. Due to the shorter length and more complex arrangement of pipe at nuclear power plants, the use of more expensive, corrosion resistant material which does not require CP may provide lower life cycle costs than cathodically protected carbon steel.

b) Piping systems at nuclear power plants are generally grounded for personnel safety and to avoid damage to pipe and appurtenances under power fault conditions. Isolating devices that provide electrical isolation of buried piping systems for CP are not typically installed in nuclear power plants and, if present, are usually shorted to station ground through external connections or contacts. This affects both the design of the CP system and challenges the system owner's ability to properly evaluate CP system performance.

c) In addition to being shorter than transmission pipelines, buried piping at nuclear power plants is more complex than transmission pipelines. Buried piping at nuclear power plants:

- **1)** May encompass a wide range in diameter, from over 3 m (10 ft) to small bore (5 cm [2 in] or smaller);
- **2)** May be very deep (2 to 15 m [7 to 49 ft]) below grade;
- **3)** May frequently cross one another;
- **4)** May be in close proximity to one another (just a few meters [feet]) horizontally and vertically;
- **5)** Is constructed from a variety of materials (e.g., carbon steel, cast iron, galvanized steel, stainless steel, copper, and aluminum);
- **6)** Is typically connected to copper grounding, reinforcing steel, galvanized steel and other dissimilar metals;
- **7)** Is often located beneath plant buildings, foundations, or other permanent structures;
- **8)** May not be electrically continuous; and
- **9)** May include mixed metallic materials or nonmetallic materials.

These conditions impact corrosion control and inspection options.

d) The material used to backfill trenches for gas and oil transmission pipelines and for piping at nuclear power plants is often substantially different. Material used to backfill oil and gas transmission pipelines is predominantly a native material and, as such, may:

1) contain substantial organic material;

2) retain water; and

3) contain large objects.

Conversely, trench backfill at nuclear power plants often has a controlled composition and size distribution (engineered backfill) or is cementitious in nature (flowable fill).

These differences affect the corrosiveness of the environment and impose different requirements on the design, installation, operation, and maintenance of CP systems. While these issues are alluded to in SP0169, they are not addressed in sufficient detail to adequately address the design, installation, operation, and maintenance of CP systems in nuclear power plants. It is the intent of this standard to provide guidance regarding issues, materials, and practices of current importance to CP systems in nuclear power plants. Specific attention will be paid to areas of divergence between buried piping at nuclear power plants and oil and gas transmission and distribution pipelines.

While the scope of this standard is limited to buried and submerged piping systems at nuclear power plants, owners of other facilities, e.g., non-nuclear power plants or petroleum refineries, may find the information contained in this standard to be of interest.

The purpose of this standard and, therefore, the acceptance criteria contained herein, is to provide for and evaluate the effectiveness of a CP system in controlling external corrosion. This standard is neither based on, nor should it be used for, assessing the useful life of a piping system. Such an assessment should include issues such as piping corrosion allowances and rates of internal corrosion. These, and related issues needed for piping life assessment, are beyond the scope of this document.
This standard is intended for use by corrosion control / cathodic protection personnel involved with the external corrosion of underground or submerged piping systems at nuclear power plants.

Except as directed by the regulatory authority having jurisdiction, this standard must be used in its entirety. Using or citing only specific paragraphs or sections can lead to misinterpretation and misapplication of the practices contained in this standard.
This standard does not designate practices for every specific situation because of the complexity of conditions to which buried or submerged piping systems at nuclear power plants are exposed.

This standard was prepared in 2020 by NACE Task Group (TG) 491, "External Cathodic Protection for Nuclear Power Plant Piping Systems." TG 491 is administered by Specific Technology Group (STG) 41, "Electric Utility Generation, Transmission, and Distribution." It is sponsored by STG 05, "Cathodic/Anodic Protection," and STG 35, "Pipelines, Tanks, and Well Casings." This standard is issued by NACE under the auspices of STG 41.

In NACE standards, the terms ***shall, must, should,*** and ***may*** are used in accordance with the definitions of these terms in the NACE Publications Style Manual. The terms ***shall*** and ***must*** are used to state a requirement, and are considered mandatory. The term ***should*** is used to state something good and is recommended, but is not considered mandatory. The term ***may*** is used to state something considered optional.

Cathodic Protection Systems for the Mitigation of External Corrosion of Buried and Submerged Metallic Piping Systems at Nuclear Power Plants

Section 1: General

1.1 This standard presents accepted methods and practices regarding the use of CP for the control of external corrosion on buried or submerged carbon steel, stainless steel, gray cast iron, ductile cast iron, copper, and aluminum piping systems at nuclear power plants. It is not intended for CP of pre-stressed concrete cylinder pipe (PCCP) or other reinforced concrete pressure pipes. Additional guidance regarding the design, installation and testing of CP systems for PCCP and other reinforced concrete pressure pipes can be found in NACE SP0100, "Cathodic Protection to Control External Corrosion of Concrete Pressure Pipelines and Mortar-Coated Steel Pipelines for Water and Waste Water Service."[3] This standard may be useful at facilities other than nuclear power plants, which contain complex networks of buried or submerged piping, which may be composed of more than one material and may or may not be grounded.

1.2 This standard addresses the design of CP systems in nuclear power plants for new piping systems, existing coated piping systems and existing uncoated piping systems. For each type of system, information is provided concerning the effects of grounding of the piping system to be protected on the design of the CP system. This standard also introduces design concepts for new piping systems, which will assist in the design, operation, testing, or maintenance of a CP system (Sections 5 and 6).

1.3 This standard also presents accepted methods and practices for the installation, operation (including acceptance criteria), testing, and maintenance of CP systems in nuclear power plants (Sections 7 and 8).

1.4 This standard presents criteria and procedures which may be used to determine the conditions under which a pipe or piping system need not be cathodically protected (Section 4).

1.5 The provisions of this standard are intended to be applied under the direction of competent persons who, by reasons of knowledge of the physical sciences and the principles of engineering and mathematics, acquired by education and related practical experience, are qualified to engage in the practice of corrosion control on buried or submerged metallic piping systems.

Note: Such persons might be, but are not limited to, registered professional engineers or persons recognized as Corrosion Specialists or CP Specialists by NACE International Institute, if their professional activities include suitable experience in external corrosion control of buried or submerged metallic piping systems.

1.6 Deviation from this standard might be warranted in specific situations, provided that the responsible corrosion control personnel are able to demonstrate that the objectives expressed in this standard have been achieved.

1.7 This standard is not intended for use in the control of internal corrosion of buried or submerged piping systems.

1.8 This standard is written using U.S. regulatory definitions and wording. Other nations may have similar but not identical definitions and wording to describe their specific regulatory requirements.

Section 2: Definitions[(1)]

Definitions are provided in this section when the term used: (1) is not defined in NACE/ASTM[(2)] G193;[4] (2) may not be familiar to a corrosion control practitioner who may be using this standard; or (3) may not be consistent with common usage or understanding. Unless specifically defined here, (1) terms which are defined in NACE/ASTM G193 shall be construed in accordance with the G193 definition; (2) terms not defined in G193 shall be construed in accordance with common usage related to corrosion engineering.

Definitions:

Alternating Current (AC): An electric current that reverses its direction many times a second at regular intervals, typically used in power supplies.

Backfill: (1) Material placed in a hole to fill the space around the anodes, vent pipe, and buried components of a cathodic protection system (see NACE/ASTM G193). (2) Material (native or imported) used to fill a pipe trench.

Buried: Piping which is in contact with soil or concrete. (See Underground).

Cable: One conductor or multiple conductors insulated from one another and the environment.

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(1) Definitions in this section reflect common usage among practicing corrosion control personnel and apply specifically to how the terms are used in this standard.
(2) ASTM International (ASTM), 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959.