NACE TM0212-2018
Item No. 21260
Approved 02-02-2018

Detection, Testing, and Evaluation of Microbiologically Influenced Corrosion on Internal Surfaces of Pipelines

This NACE International standard represents a consensus of those individual members who have reviewed this document, its scope, and provisions. Its acceptance does not in any respect preclude anyone, whether he has adopted the standard or not, from manufacturing, marketing, purchasing, or using products, processes, or procedures not in conformance with this standard. Nothing contained in this NACE International standard is to be construed as granting any right, by implication or otherwise, to manufacture, sell, or use in connection with any method, apparatus, or product covered by Letters Patent, or as indemnifying or protecting anyone against liability for infringement of Letters Patent. This standard represents minimum requirements and should in no way be interpreted as a restriction on the use of better procedures or materials. Neither is this standard intended to apply in all cases relating to the subject. Unpredictable circumstances may negate the usefulness of this standard in specific instances. NACE International assumes no responsibility for the interpretation or use of this standard by other parties and accepts responsibility for only those official NACE International interpretations issued by NACE International in accordance with its governing procedures and policies which preclude the issuance of interpretations by individual volunteers.

Users of this NACE International standard are responsible for reviewing appropriate health, safety, environmental, and regulatory documents and for determining their applicability in relation to this standard prior to its use. This NACE International standard may not necessarily address all potential health and safety problems or environmental hazards associated with the use of materials, equipment, and/or operations detailed or referred to within this standard. Users of this NACE International standard are also responsible for establishing appropriate health, safety, and environmental protection practices, in consultation with appropriate regulatory authorities if necessary, to achieve compliance with any existing applicable regulatory requirements prior to the use of this standard.

CAUTIONARY NOTICE: NACE International standards are subject to periodic review, and may be revised or withdrawn at any time without prior notice. NACE International requires that action be taken to reaffirm, revise, or withdraw this standard no later than five years from the date of initial publication. The user is cautioned to obtain the latest edition. Purchasers of NACE International standards may receive current information on all standards and other NACE International publications by contacting the NACE International *First*Service Department, 15835 Park Ten Place, Houston, Texas 77084, telephone +1 (281) 228-6223.

ABSTRACT

This NACE standard test method applies to the internal surfaces of pipelines, and describes types of microorganisms, mechanisms by which MIC occurs, methods for sampling and testing for the presence of microorganisms, research results, and interpretation of test results. Sections 1 through 4 of this standard discuss the technical aspects of MIC. Sections 5 through 7 discuss field equipment and testing procedures. This standard is maintained by Task Group 254.

KEYWORDS

Pipelines, MIC, test methods, internal

ISBN 1-57590-255-9

Foreword

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.

Microbiologically influenced corrosion (MIC) is corrosion affected by the presence or activity (or both) of microorganisms in biofilms on the surface of the corroding material. Many materials, including most metals and some nonmetallics, can be degraded in this manner. Microbiologically mediated reactions can alter both rates and types of electrochemical reactions in a corrosion cell. These reactions influence general and localized corrosion, (inclusive of pitting and crevice corrosion), differential aeration cells, concentration cells, dealloying, and galvanic corrosion. Therefore, MIC investigations require microbiological, chemical, and metallurgical testing for proper diagnosis. The conclusion that MIC has taken place should be based on the preponderance of circumstantial evidence. Microorganisms are often resistant to many control methods and can pose a serious internal corrosion threat to pipelines.

This NACE standard test method applies to the internal surfaces of pipelines, and describes types of microorganisms, mechanisms by which MIC occurs, methods for sampling and testing for the presence of microorganisms, research results, and interpretation of test results. Sections 1 through 4 discuss the technical aspects of MIC. Sections 5 through 7 discuss field equipment and testing procedures. This standard is intended for use by pipeline operators, pipeline service providers, government agencies, and any other persons or companies involved in planning or managing pipeline integrity.

Portions of Sections 3 and 4 of this standard are excerpted from Peabody's Control of Pipeline Corrosion, Chapter 14, "Microbiologically Influenced Corrosion."[1]

This standard test method was prepared by Task Group (TG) 254, "Microbiologically Influenced Corrosion on Internal Surfaces of Pipelines: Detection, Testing, and Evaluation—Standard Test Method." It was revised by TG 254 in 2016. TG 254 is administered by Specific Technology Group (STG) 35, "Pipelines, Tanks, and Well Casings." This standard is issued by NACE under the auspices of STG 35.

Detection, Testing, and Evaluation of Microbiologically Influenced Corrosion on Internal Surfaces of Pipelines

Section 1: General

1.1 While the evaluation, monitoring, and mitigation of MIC cannot be prescribed in one particular manner for any given pipeline, this standard describes methodologies by which the appropriate tools and techniques may be selected and practically applied. The methods presented in this standard represent the general consensus of industry experts in pipeline corrosion and microbiology at the time this standard was published.

1.2 Appendix A (Nonmandatory) provides a site inspection and testing checklist and Appendix B (Nonmandatory) provides an example of pipeline system assay data.

1.3 The term "pipeline" as used in this standard generally refers to any pipe, tank, vessel, or component of a pipeline system for which the mechanism of internal MIC is of interest to the user of this standard.

Section 2: Definitions

The definitions of many of the corrosion-related terms used in this test method can be found in NACE/ASTM[1] G193.[2] Other terms not included therein that have been used in this test method are defined as follows:

Abiotic: The absence of living organisms, their biological components, or the metabolic activities of living organisms.

Acid-producing bacteria (APB): Aerobic or anaerobic bacteria that produce organic acids as an end product of their metabolism. A few organisms (e.g., *Thiobacillus*), also are capable of producing mineral acids (typically under aerobic conditions).

Aeration: (1) Exposing to the action of air. (2) Causing air to bubble through. (3) Introducing air into a solution by spraying, stirring, or similar method. (4) Supplying or infusing with air, as in sand or soil. (5) The introduction of air into the pulp in a flotation cell to form air bubbles.

Aerobic: Containing air or free molecular oxygen.

Aerobic microorganism (aerobe): A microorganism that uses oxygen as the final electron acceptor in metabolism.

Anaerobic microorganism (anaerobe): A microorganism that does not require oxygen for metabolism.

Archaea: Domain of unicellular microorganisms that are genetically distinct from the domains *Bacteria* and *Eukarya,* which often inhabit extreme environmental conditions. Archaea include halophiles (microorganisms that may inhabit extremely salty environments), methanogens (microorganisms that produce methane), and thermophiles (microorganisms that can thrive in extremely hot environments). *Archaeoglobus* is a common archaeon.

Archaeoglobus: Archaeoglobus is a common organism in the phylogenic domain Archaea. These microorganisms that grow at high temperatures between 60 and 95 °C, with optimal growth at 83 °C (ssp. A. fulgidus VC-16).[3] They are sulfate-reducing archaea, coupling the reduction of sulfate to sulfide with the oxidation of many different organic carbon sources, including complex polymers. Archaeoglobus species have been isolated from oil reservoirs and production systems; however, this group of microorganisms is normally not measured with current culturing techniques.

[1] ASTM International (ASTM), 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959.

Autoclave: A pressurized, steam-heated vessel used for sterilization.

Bacteria: Domain of unicellular microorganisms which are genetically distinct from the domains *Archaea* and *Eukarya.*

Bacterium (pl. bacteria): An organism which phylogenetically falls into the domain *Bacteria.*

Biofilm: Microbial growth at an interface in which individual cells are bound within a matrix of extracellular polymeric materials.

Biotic: Involving the presence or metabolic activities of living organisms.

Carbohydrate: Any of the group of organic compounds composed of carbon, hydrogen, and oxygen including sugars, starches, and celluloses.

Culture medium: A sterile solution or other substrate formulated to promote the growth of a particular type or group of microorganisms. (Also called *growth medium*).

4',6-diamidino-2-phenylindole (DAPI): A stain for optical microscopy that targets the deoxyribonucleic acid (DNA) in all (i.e., living and inactive) microbial cells.

Denaturing gradient gel electrophoresis (DGGE): A molecular microbiological method used to profile the most abundant microbial groups in a sample.

Dissimilatory: Metabolic reactions in which an oxidant is used as an electron acceptor and material is not incorporated into the cell (e.g., dissimilatory sulfate or nitrate reduction), metabolic changes that convert complex molecules into simple ones.

Eukaryotes: Cells having a true nucleus, bound by a double membrane. Prokaryotic cells have no nucleus.

Facultative: Capable of growing either with or without the presence of a specific environmental factor, e.g., oxygen.

Fluorescence in situ hybridization (FISH): A molecular microbiological method used for enumeration of microorganisms. The method is based on gene probes targeting ribosomal ribonucleic acid (RNA) (16S or 23S rRNA) in microbial cells. Only living and active cells contain sufficient ribosomes that can be detected in FISH. Gene probes consist of two parts: (1) an artificial DNA strand complementary to the ribosomal RNA in the target cell; and (2) a fluorescing molecule covalently attached to the probe that enables observation of the target microorganism in the microscope.

Fungi: Nucleated, usually filamentous, spore-bearing parasitic microorganisms devoid of chlorophyll, which include molds, mildews, smuts, mushrooms, yeasts, and others. Fungi are often found to degrade fuel (e.g., fuel spoilage).

Growth: An increase in the quantity of metabolically active protoplasm, accompanied by an increase in cell numbers, cell size, or both.

Growth medium: See *culture medium*.

Inoculum: A small quantity of microorganisms used to start a new culture.

Inorganic acid: A compound composed of hydrogen and a nonmetal element or radical; examples are hydrochloric acid (HCl) and sulfuric acid (H_2SO_4). A substance that yields hydrogen ions when dissolved in water and that can act as a proton donor.