Test Methods for Corrosion of Coated Steel in Aqueous Environments

K. Gebreselassie[1], C. Vipulanandan[1] and D. Richardson[2]
[1]Center for Innovative Grouting Materials and Technology (CIGMAT)
Department of Civil and Environmental Engineering
University of Houston, Houston, Texas 77204-4003
Email:kagebreselassie@uh.edu, cvipulanandan@uh.edu, Phone: (713) 743-4278
[2]Program Manger –RPSEA, Sugar Land, Texas 77478

Abstract: Standard test methods available for corrosion study of coated steel in aqueous environments were reviewed. Several standard test methods focused on the quality controls of coatings while others on resistance of coatings against corrosion. The standard test methods related to corrosion of coated steel do not cover seawater environments. The standard test methods can be used directly and indirectly to detect the presence of corrosion in coated steel in seawater environment.

1. Introduction:

Corrosion is a naturally occurring phenomenon commonly defined as the deterioration of a substance (usually a metal) or its properties because of a reaction with its environment. According to the 1999 to 2001 U.S. corrosion study, the direct cost of metallic corrosion was $276 billion on an annual basis. This represents 3.1% of the U.S. Gross Domestic Product. Corrosion is the primary factor affecting the longevity and reliability of pipelines that transport crucial energy sources throughout the nation. The average annual corrosion-related cost is estimated at $7 billion to monitor, replace, and maintain these assets (NACE). The corrosion-related cost of operation and maintenance makes up 80% of this cost (NACE). Various time-proven methods for preventing and controlling corrosion depend on the specific material to be protected; environmental concerns such as soil resistivity, humidity, and exposure to saltwater or industrial environments; the type of product to be processed or transported; and many other factors. The most commonly used methods include organic and metallic protective coatings; corrosion resistant alloys, plastics, and polymers; corrosion inhibitors; and cathodic protection. It is worth mentioning that coatings may delay initiation of corrosion by 10 – 20 years.

2. Objectives:

The objective of this study was to review and summarize the test methods (including specimen size, test type, environment, and temperature) available to investigate corrosion on coated steel particularly in aqueous environments.

3. Literature Review:

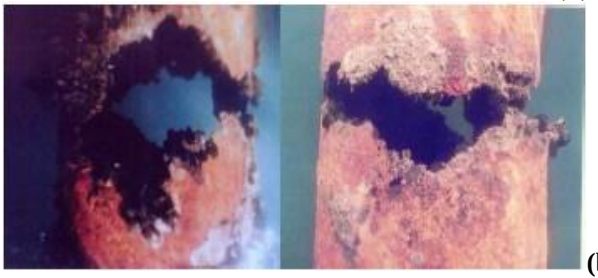
Based on the literature review, available test methods related to coated steel corrosion in water environment are summarized in Table 1. Their accuracy and applicability for offshore structures particularly steel casing of oil drilling works are given as remarks. Corrosion mechanism for steel under water can be described as follows.

Corrosion mechanism

Anode: $Fe \rightarrow Fe^{2+}+2e^{-}$ (Corrosion) ---------- (1)

Cathode: $O_2+2H_2O+4e^{-} \rightarrow 4OH^{-}$ ---------- (2)

(a)



(b)

Figure 1. Deterioration of steel pipe pile

Table 1. Few summaries of test methods

Publication	ASTM G62 – 07[1]	ASTM D1654 – 08[2]	Remark
Year, reapproved	2013	2008	-
Objective	Detecting holidays in pipeline type coatings	Evaluating corrosion performance of coating system	Test methods related to coated steel
Material composition	Tap water	NA	-
Material form	Steel pipe, coatings	Metals, organic and metal coatings	Applicable to coatings of steel
Environment	Water, soil, atmosphere	Atmosphere	Any environment addressed
Cause of corrosion	NA	NA	Both methods not consider
Evaluating factors	Pinholes, voids, thin spots or faults	Blistering associated with corrosion, loss of adhesion	Voids & loss of adhesion can be resulted from corrosion products
Test type	Applying voltages	Scribing & exposing	Can be NDT or destructive test type
Test specimen size	Typical length of production-coated pipe	Any size of coated specimen/metal	Any size
Weight loss meas.	NA	NA	Both methods not consider
Accuracy	Depends on uniformity of production process of specimen	Dependent on level of measurement precision	Dependent on specimen preparation and measurement precision
Remark	It is quick test method that can be used on any thickness of coating. Up to 20,000 V can be utilized	Applicable to paint related coatings	Test duration and coating type are considered

[1] **Standard Test Methods for Holiday Detection in Pipeline Coatings**

[2] **Standard Test Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments**

4. Discussion: The scope of ASTM G62 – 07 is to detect holidays in pipeline type coatings. The standard test has two separate methods. One method (Method A) is used to detect pinholes and voids in coatings with thickness of from 0.0254 mm to 0.254 mm using an applied voltage of less than 100 V. The other method (Method B) is used to detect holidays including thin spots in the coating with any thickness using high voltage up to 20,000 V. Method A provides a quick and safe method for determining presence of holidays in the coating. Method B can be used to verify minimum coating thickness as well as voids in quality-control applications. Both methods rely on electrical contact being made through the pipeline coating because of a holiday or a low-resistance path created by metal particles, or thin spots in the coating. The scope of ASTM D1654 – 08 covers the treatment of coated specimens for accelerated and atmospheric exposure test and their subsequent evaluation in respect to corrosion, blistering associated with corrosion, loss of adhesion at a scribe mark, or other film failure. This method provides a means of evaluation and comparing basic corrosion performance of the substrate, pretreatment, or coating system after exposure to corrosive environments.

5. Conclusion: In conclusion, the standard test methods related to coated steel exposed to different corrosive environment were reviewed. Some test standards focused on the quality controls of coatings while others focused on resistance of coatings against corrosion. Although the reviewed test methods do not focus on detecting corrosion on coated steel in seawater environment, they can be used to directly and indirectly detect the presence of corrosion in coated steel in seawater environment.

6. Acknowledge: This study was supported by CIGMAT with partial funding from various industries.

7. References: 1. American Society for Testing and Materials standards. 2. Corrosion Costs and Preventive Strategies in the United States, NACE International. 3. Mohamed A. El-Reedy, Offshore Structures: Design, Construction and Maintenance, 2012 Elsevier, Inc.