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Impressed Current Laboratory Testing of Aluminum and Zinc Alloy Anodes

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ABSTRACT

Describes a quality assurance procedure for determining the potential and current capacity characteristics under laboratory conditions for aluminum and zinc alloy anodes used for cathodic protection. The procedure screens various heats or lots of anodes to determine performance consistency on a regular basis from lot to lot. One method for anode potential evaluation and two methods (mass loss and hydrogen evolution) for current capacity evaluations are described. Performance criteria and sampling frequency are left to the discretion of users of the standard.

KEYWORDS

anodes, cathodic protection, testing.

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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.*

This standard test method describes a quality assurance procedure for determining the potential and current capacity characteristics under laboratory conditions for aluminum and zinc alloy anodes used for cathodic protection (CP). Field performance of anodes should be evaluated to correspond to actual anode performance.

This standard is intended primarily for users, designers, and manufacturers involved with the application of CP in marine environments. This standard can be used by manufacturers and users of aluminum and zinc anodes for quality control verification. The most common usage is expected to be by manufacturers to meet quality control requirements requested by the purchasing user. This standard is based on experiences from the paper by J.F. Brown Jr., "Quality Control Testing of Aluminum Anodes: T-7L-2 Task Group Progress Report,"[1] and on ANSI/NACE SP0115/ISO 15589-2[2] and Military Specification MIL-DTL-18001.[3]

This standard was originally prepared in 1990 by NACE International Task Group T-7L-2 on Aluminum Anode Quality Control, a component of Unit Committee T-7L on Cathodic Protection, in conjunction with ASTM(1) Task Group G01-09-02 T-1. It was revised by Task Group T-7L-12 in 1998, reaffirmed by Specific Technology Group (STG) 30, "Oil and Gas Production: Cathodic Protection," in 2006, and revised in 2012 by Task Group (TG) 459, "Review and Revise as Necessary NACE Standard TM0190-2006." It was reaffirmed by STG 30 in 2017. It is issued by NACE under the auspices of STG 30. These committees are composed of industry representatives, including producers, consumers, and interested individuals.

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

NACE International Standard Test Method (TM0190-2017)

Impressed Current Laboratory Testing of Aluminum and Zinc Alloy Anodes

Figures

Tables

Section 1: General

1.1 This standard test method describes a laboratory procedure for determining the potential and current capacity characteristics of aluminum and zinc alloy anodes used for CP. It provides a means for screening various heats or lots of anodes to determine performance consistency on a regular basis from lot to lot. Items such as sampling frequency and performance criteria (i.e., test values and intermediate times) are left to the discretion of the user of the test method.

1.2 One test method for anode potential evaluation and two test methods for anode current capacity evaluations are described.

1.3 The actual values obtained in these tests should not be used for design purposes because they represent laboratory testing.

1.4 This procedure can be validated by using zinc anode samples as a reference in the test to verify results of aluminum anodes tested. Zinc samples shall be as defined in ASTM B418[4] or Military Specification MIL-DTL-18001 for zinc anodes.

1.5 This procedure was evaluated by testing alloys of Al-Zn-Sn, Al-Zn-Hg, Al-Zn-In-Mg, and MIL-DTL-18001 zinc of the respective nominal alloy composition ranges shown in Table 1. The results of the test are reported in Paper No. 346 presented at CORROSION/84.[1]

1.6 The precision of the test has not been validated. The scatter in the test results is considered to result from heterogeneities in aluminum alloy anode materials in general, as tested, rather than the test method itself. Only anode materials exhibiting good, reproducible performance (in accordance with this test method) and meeting manufacturer or user specifications are acceptable.

1.6.1 Ranges of performance from those alloys tested are listed in Table 2.

Table 1
Nominal Alloy Composition Ranges for Anodes Tested (%)

	Al-Zn-Sn	**Al-Zn-Hg**	**Al-Zn-In-Mg**	**Zinc (MIL-DTL-18001)**
Zn	6.0 to 8.0	1.25 to 2.00	1.0 to 3.0	Remainder
Sn	0.10 to 0.20	—	—	—
Si	—	—	—	0.125 max.
Hg	—	0.030 to 0.08	—	—
Pb	—	—	—	0.006 max.
Mg	—	—	0.50 to 1.0	—
In	—	—	0.20	—
Fe	0.10 max.	0.10 max.	0.10 max.	0.005 max.
Cd	—	—	—	0.025 to 0.15
Cu	0.003 max.	0.003 max.	0.010 max.	0.005 max.
Al	Remainder	Remainder	Remainder	0.10 to 0.50

Table 2
Range of Evaluation Results

Alloy	**Operating Potential (SCE[A]-mV)**	**Hydrogen Evolution (% Efficiency)**	**Impressed Current Capacity A-h/kg**	**A-h/lb**
Al-Zn-Sn	940 to 1,176	70 to 94	1,014 to 2,711	460 to 1,230
Al-Zn-Hg	830 to 1,114	96	2,623 to 2,949	1,190 to 1,338
Al-Zn-In-Mg	1,032 to 1,140	90	2,354 to 2,742	1,068 to 1,244
Zinc	969 to 1,051	98	754 to 804	342 to 365

[A] Saturated calomel electrode.

1.6.2 Al/Zn/In alloys have been found suitable for this test method (see ANSI/NACE SP0115/ISO 15589-2 and Military Specification MIL-DTL-24779).[5]

Section 2: Summary of Test Method

2.1 A 16,000 mm^3 (1.0 in^3) sample of alloy anode material shall be immersed in synthetic seawater (see ASTM D1141[6]) at ambient temperature for two weeks (336 h), while anodically polarized at an impressed current density value of 6.2 A/m^2 (4.0 mA/in^2). Potentials shall be measured periodically and current capacity determined by the method(s) described in Paragraph 2.4.

2.2 The test shall be conducted with the synthetic seawater electrolyte at room temperature of 23 ± 3 °C (73 ± 5 °F), or other temperature specified by the client, and shall be recorded each time potential measurements are made.

2.3 Anode potentials shall be measured with a standard reference electrode, such as an SCE, at 3 h, 24 h, 48 h, 72 h, and 336 h. Potentials may be taken more frequently if desired.

2.3.1 For tests conducted at temperatures other than room temperature, consideration should be given to the impact of the test temperature on the potential measurement.

2.4 Anode current capacity shall be determined by the Mass Loss Method. This method may be supplemented by the Hydrogen Evolution Method.

2.4.1 Mass Loss Method: The total current passed through the system shall be measured by a coulometer. Anode mass loss shall be determined at the end of the two-week test when the samples are removed, cleaned, and weighed. Mass loss current capacities shall be determined from knowledge of the total charge passed through the system and the mass loss of the anode samples.

2.4.2 Hydrogen Evolution Method: Hydrogen that evolved from the anode as a result of local cell action under impressed conditions shall be collected in a graduated buret after 72 h of testing, and the anode efficiency shall be calculated. The volume of gas collected during the collection time, the elapsed time, and the current flow through the anode samples shall be used for hydrogen evolution efficiency calculations.

2.4.3 For tests conducted at temperatures other than room temperature, consideration should be given to the impact of the test temperature on the current capacity values.

2.5 The causes of noble (more positive) potential results or low current capacity, or both, measured on a particular lot of anodes relative to established benchmarks for a particular alloy, should be investigated.

2.6 Zinc anode samples conforming to ASTM B418 should be used in the test as a reference material. Instructions for cleaning zinc samples before testing are given in ASTM G1.7

Section 3: Test Apparatus

3.1 Anode Test Cell: The container (1.5 L [0.40 gal]), shown in Figure 1 with a titanium sample support rod, steel screen cathode, and gas buret for hydrogen collection, shall be filled with synthetic seawater to a level 13 mm (0.50 in) from the top. A minimum distance of 19 mm (0.75 in) between the anode sample and the cathode screen should be maintained.

3.1.1 If the steel cathode is galvanized, the coating shall be removed from the screen prior to the first test. This may be accomplished by immersing the screen in 10% nitric acid ([HNO_3], [90 parts water, 10 parts nitric acid by volume]) at 49 to 66 °C (120 to 150 °F) until the coating is removed. The screen should be rinsed in reagent water (see ASTM D1193)[8] to remove the acid. The nitric acid solution shall be handled with care.

3.1.2 A stainless steel beaker or carbon steel container may be used as a cathode, or a plastic test cell with stainless steel or carbon steel mesh cathode may be used as shown in Figure 2.

3.2 Copper Coulometer: The coulometer (such as the type shown in Figure 3) shall be filled with copper coulometer solution as described in Paragraph 4.3. Copper plates shall be a minimum of 99.9% purity.

3.2.1 An electronic coulometer of sufficient precision (± 1%) may be substituted for the copper coulometer.

3.3 Power Supply: A constant-current direct current (DC) power supply should be used in conjunction with the DC milliammeter, as shown in Figure 4. The DC impressed current required in this test shall be 24 ± 0.2 mA.

3.3.1 A voltage-regulated DC power supply capable of regulation at 24 mA with a 1% deviation of full-scale adjustment may be substituted for the constant current supply.

3.4 Any number of anode samples may be tested at one time by wiring multiple test cells in series in the circuit, as shown in Figure 4, provided that the power supply is capable of supplying sufficient voltage to maintain the impressed current at 24 ± 0.2 mA through each test cell.

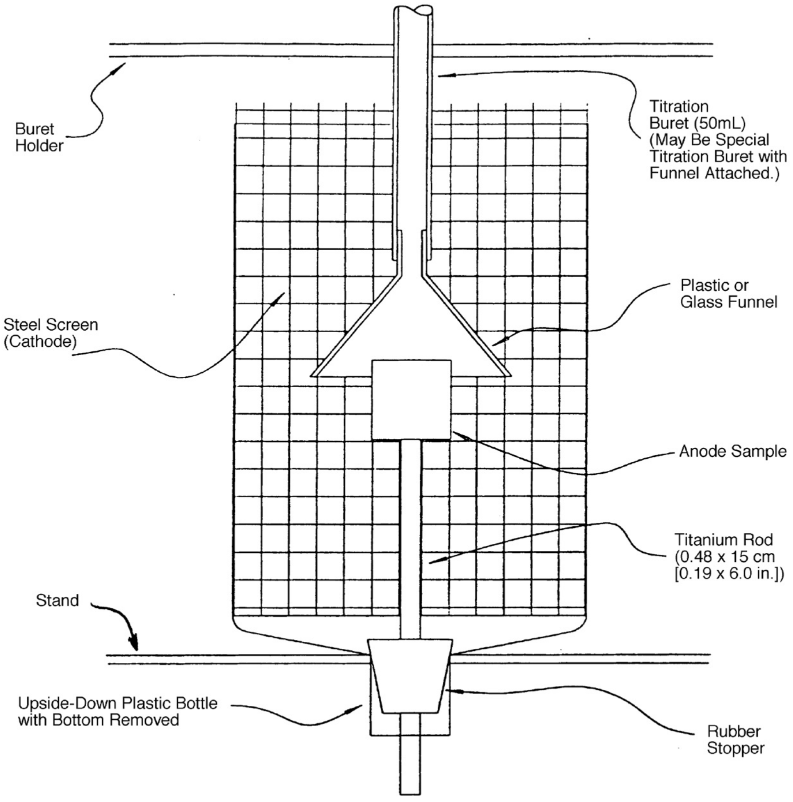

Figure 1: Hydrogen Evolution Test Set-Up