Impressed Current Laboratory Testing of Aluminum and Zinc Alloy Anodes

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 or she 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 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 assumes no responsibility for the interpretation or use of this standard by other parties and accepts responsibility for only those official NACE interpretations issued by NACE in accordance with its governing procedures and policies which preclude the issuance of interpretations by individual volunteers.

Users of this NACE 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 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 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CAUTIONARY NOTICE: NACE standards are subject to periodic review, and may be revised or withdrawn at any time in accordance with NACE technical committee procedures. NACE requires that action be taken to reaffirm, revise, or withdraw this standard no later than five years from the date of initial publication and subsequently from the date of each reaffirmation or revision. The user is cautioned to obtain the latest edition. Purchasers of NACE standards may receive current information on all standards and other NACE publications by contacting the NACE FirstService Department, 15835 Park Ten Place, Houston, TX 77084-5145 (telephone +1 281-228-6200).

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.
Foreword

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 15589-22 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 ASTM10 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.

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

Impressed Current Laboratory Testing of Aluminum and Zinc Alloy Anodes

1. General ......................................................................................................................................... 4
2. Summary of Test Method ............................................................................................................ 5
3. Test Environment ....................................................................................................................... 5
4. Test Conditions .......................................................................................................................... 8
5. Test Specimens .......................................................................................................................... 9
6. Test Equipment ........................................................................................................................... 9
7. Test Procedure ........................................................................................................................... 10
8. Reporting of Test Results .......................................................................................................... 12
   References ................................................................................................................................... 13
   Bibliography ............................................................................................................................... 13

Figures

Figure 1: Hydrogen Evolution Test Set-Up .................................................................................... 6
Figure 2: Alternate Test Cell Set-Up (Without Hydrogen Evolution Test) ............................... 7
Figure 3: Sacrificial Copper Plate and Copper Coulometer ....................................................... 7
Figure 4: Wiring Diagram .............................................................................................................. 8

Tables

Table 1: Nominal Alloy Composition Ranges for Anodes Tested (%) ........................................ 4
Table 2: Range of Evaluation Results .......................................................................................... 4
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 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.

1.6 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 (%)

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Zn</th>
<th>Sn</th>
<th>Si</th>
<th>Hg</th>
<th>Pb</th>
<th>Mg</th>
<th>In</th>
<th>Fe</th>
<th>Cd</th>
<th>Cu</th>
<th>Al</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al-Zn-Sn</td>
<td>6.0 to 8.0</td>
<td>0.10 to 0.20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.10 max.</td>
<td></td>
<td>0.003 max.</td>
<td>Remainder</td>
</tr>
<tr>
<td>Al-Zn-Hg</td>
<td>1.25 to 2.00</td>
<td></td>
<td></td>
<td>0.030 to 0.08</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.10 max.</td>
<td>0.003 max.</td>
<td>Remainder</td>
</tr>
<tr>
<td>Al-Zn-In-Mg</td>
<td>1.0 to 3.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.010 max.</td>
<td>Remainder</td>
</tr>
<tr>
<td>Zinc (MIL-DTL-18001)</td>
<td>Remainder</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.10 to 0.50</td>
<td>Remainder</td>
</tr>
</tbody>
</table>

### Table 2

Range of Evaluation Results

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Operating Potential (SCE(^{(a)\text{,mV}}))</th>
<th>Hydrogen Evolution (% Efficiency)</th>
<th>Impressed Current Capacity (A-h/kg)</th>
<th>Impressed Current Capacity (A-h/lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al-Zn-Sn</td>
<td>940 to 1,176</td>
<td>70 to 94</td>
<td>1,014 to 2,711</td>
<td>460 to 1,230</td>
</tr>
<tr>
<td>Al-Zn-Hg</td>
<td>830 to 1,114</td>
<td>96</td>
<td>2,623 to 2,949</td>
<td>1,190 to 1,338</td>
</tr>
<tr>
<td>Al-Zn-In-Mg</td>
<td>1,032 to 1,140</td>
<td>90</td>
<td>2,354 to 2,742</td>
<td>1,068 to 1,244</td>
</tr>
<tr>
<td>Zinc</td>
<td>969 to 1,051</td>
<td>98</td>
<td>754 to 804</td>
<td>342 to 365</td>
</tr>
</tbody>
</table>

\(^{(a)}\) Saturated calomel electrode.