INCH-POUND
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DETAIL SPECIFICATION

REFERENCE CELL, IMPRESSED CURRENT CATHODIC PROTECTION (ICCP) – SILVER-SILVER CHLORIDE

This specification is approved for use by the Naval Sea Systems Command, Department of the Navy, and is available for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification covers circular silver-silver chloride flush type reference electrodes used in impressed current cathodic protection systems. The reference electrode provides the control signal to the impressed current system and may be used to monitor the system operation. It includes features of design and fabrication of these electrodes, including alternate components.

1.2 Classification. Silver-silver chloride reference cells are of the following types, grades, applications and performance levels:

1.2.1 Type.

a. Type I – Standard Cell

b. Type II – Diver Replaceable Cell

1.2.2 Grade.

a. Grade A – Mesh Reference Cell

b. Grade B – Plate Reference Cell

1.2.3 Applications.

a. Application I – Surface Ship

b. Application II – Submarine

1.2.4 Performance levels.

a. Performance A – Standard Performance

b. Performance B – High Performance

Comments, suggestions, or questions on this document should be addressed to: Commander, Naval Sea Systems Command, ATTN: SEA 05M2, 1333 Isaac Hull Avenue, SE, Stop 5160, Washington Navy Yard DC 20376-5160 or emailed to CommandStandards@navy.mil, with the subject line “Document Comment”. Since contact information can change, you may want to verify the currency of this address information using the ASSIST Online database at http://assist.daps.dla.mil.

1.3 Part or identifying number (PIN). PINs to be used for silver-silver chloride reference cells acquired to this specification are created as follows:

M	**23919**	**-**	**X**	**X**	**X**	**X**
Prefix for Military Specification	Specification Number		Type (see examples below)	Grade (see examples below)	Application (see examples below)	Performance (see examples below)

Type code		**Grade code**		**Application code**		**Performance code**	
I	1	A	A	I	1	A	A
II	2	B	B	II	2	B	B
Example: M23919-1A1A – Standard Cell, Mesh Reference Cell, Surface Ship, Standard Performance							

2. APPLICABLE DOCUMENTS

2.1 General. The documents listed in this section are specified in sections 3, 4, or 5 of this specification. This section does not include documents cited in other sections of this specification or recommended for additional information or as examples. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirements of documents cited in sections 3, 4, or 5 of this specification, whether or not they are listed.

2.2 Government documents.

2.2.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

DEPARTMENT OF DEFENSE SPECIFICATIONS

MIL-S-901 - Shock Tests, H.I. (High-Impact) Shipboard Machinery, Equipment, and Systems, Requirements for

(Copies of this document are available online at http://assist.daps.dla.mil/quicksearch/ or from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094.)

2.3 Non-Government publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

ASTM INTERNATIONAL

ASTM E11 - Standard Specification for Wire Cloth and Sieves for Testing Purposes

(Copies of this document are available from ASTM International, 100 Barr Harbor Dr., P.O. Box C700, West Conshohocken, PA 19428-2959 or online at www.astm.org.)

SAE INTERNATIONAL

SAE-AMS-P-83461	-	Packing, Preformed, Petroleum Hydraulic Fluid Resistant, Improved Performance at 275 °F (135 °C) (DoD adopted)
SAE-AS8660	-	Silicone Compound NATO Code Number S-736 (DoD adopted)

(Copies of these documents are available from SAE World Headquarters, 400 Commonwealth Drive, Warrendale, PA 15096-0001 or online at www.sae.org.)

2.4 Order of precedence. Unless otherwise noted herein or in the contract, in the event of a conflict between the text of this document and the references cited herein (except for related specification sheets), the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. REQUIREMENTS

3.1 First article. When specified, a sample shall be subject to first article inspection in accordance with 4.2.

3.2 Recycled, recovered, or environmentally preferable materials. Recycled, recovered, or environmentally preferable materials should be used to the maximum extent possible, provided that the material meets or exceeds the operational and maintenance requirements, and promotes economically advantageous life-cycle costs.

3.3 Construction.

3.3.1 Silver-silver chloride electrode element.

3.3.1.1 Chemical purity. The silver wire used in fabricating the mesh/plate shall not contain less than 99.95 percent silver. The silver chloride (AgCl) coating shall also have a metal basis purity of no less than 99.95 percent. (see 4.5.7)

3.3.1.2 Cleaning. The silver mesh/plate shall be cleaned in accordance with 4.5.8.

3.3.1.3 Application of AgCl coating. Electroplating or hot dipping are approved methods of AgCl coating processes. Sintering is not an approved method of coating the silver mesh/plate unless the process has been approved by NAVSEA.

3.3.1.4 Surface area. In order to achieve adequate surface area, the Grade A silver element shall have a mesh size of 40 or finer. For a Grade B element, the final surface area of the plate shall be no less than 3.52 centimeters squared or as approved by NAVSEA. (see 4.5.9)

3.3.1.5 Life. The life expectancy of a reference cell shall be 12 years without degradation at input impedance of the reference cell monitoring circuit. (see 4.5.10)

3.3.2 Electrical connection. The pin is made out of a noble material and plated in 99.95 percent silver and has a measured resistance less than 1.0 ohms. Type II reference cells shall be constructed such that the connection to the pin remains dry and un-oxidized after underwater replacement. (see 4.5.11)

3.3.3 Assembly.

3.3.3.1 Material. The reference cell assembly should be made of a non-conductive material to ensure that there is isolation (no shorting or grounding) between the reference cell and the hull, preferably poly-vinyl chloride.

3.3.3.2 Pressure. The reference cell assembly shall be able to withstand the design pressure depending on the class/hull of the specific vessel. After testing both Performance A and B reference cell assemblies each shall show no evidence of mechanical damage, water leakage or impaired electrical characteristics. (see 4.5.6)

3.3.3.3 Shock. The reference cell assembly shall be certified as shock Grade B. (see 4.5.12)

3.3.4 O-rings. O-rings for the hub of the base assembly should be circular rubber rings conforming to SAE-AMS-P-83461. Sealing grease for installation of the O-rings should conform to SAE-AS8660.

3.3.5 Fasteners. The fasteners used to attach the assembly to the structure to be protected should be made from corrosion-resistant material, preferably nylon.

3.4 Environmental performance requirements.

3.4.1 Accuracy/offset. Performance A cells shall have a normalized measurement within ±10 millivolts DC compared to the E224N-P In-Vivo Metric (IVM) standard reference cell, or equivalent standard cell. Performance B cells shall have a normalized measurement within ±4 millivolts DC as compared to the model E224N-P IVM standard reference cell, or equivalent cell, and within ±2 millivolts DC of all other Performance B cells in the lot being tested. (see 4.5.2)

3.4.2 Stability. Performance B reference cells must maintain a stability of ±1 millivolt DC shift versus the E224N-P IVM standard reference cell. The maximum allowable peak-to-peak difference in normalized potentials between any two reference cells in test during a 14-day test period shall be 2 millivolts DC under constant environmental conditions. (see 4.5.2)

3.4.3 Environmental linearity/drift.

3.4.3.1 Static drift. For Performance B reference cells, the maximum change between any two reference cell elements shall not exceed 0.6 millivolt DC under constant environmental conditions over 14 days. (see 4.5.3)

3.4.3.2 Temperature linearity. For Performance B reference cells, the maximum absolute difference in slope between any two reference cell elements shall not exceed 0.035 millivolt DC/°F when tested at temperatures from 40 °F to 90 °F over 336 hours. (see 4.5.4)

3.4.3.3 Water resistivity linearity. For Performance B reference cells, the maximum absolute difference in slope between any two reference cell elements shall not exceed 0.03 millivolt DC/(ohm-centimeter) when tested at water resistivities between 18 ohm-centimeters and 288 ohm-centimeters. (see 4.5.5)

4. VERIFICATION

4.1 Classification of inspections. The inspection requirements specified herein are classified as follows:

a. First article inspection (see 4.2).

b. Conformance inspection (see 4.3).

4.2 First article inspection. First article inspection shall be performed on three sample reference cells of each style of configuration. When a first article sample is required (see 3.1). This inspection shall include all tests of 4.5.

4.3 Conformance inspection. Conformance inspection shall include the tests of 4.5.1 to 4.5.5, and 4.5.7 to 4.5.11.

4.3.1 Lot. For the purpose of sampling, a lot shall consist of those reference cells of each specified classification from the same production run offered for delivery at one time. However, this lot shall not exceed 200 prepared reference cells.

4.3.2 Sampling for examination. From each lot specified in 4.3.1, a minimum of three cells shall be tested, including one of any unique configuration (see Table I).

TABLE I. Sampling for examination.

Lot size	Sample size
3-25	3
26-50	5
51-90	6
91-200	7

4.3.3 Sampling for testing. Sampling for the purpose of testing shall be conducted as dictated by the individual test procedures of 4.5.

4.3.4 Noncompliance. If a sample fails to pass any of the production quality conformance inspections and tests in 4.2, the lot shall be considered rejected. When specified (see 6.2), all rejected samples shall be returned to the manufacturer for rework or replacement. Shipping of rejected samples shall occur at no expense to the Government.

4.4 Summary of requirements and tests/examinations. Table II summarizes the requirements with reference sections and corresponding tests/examinations for verification of satisfying each requirement.

TABLE II. Summary of requirements and tests/examinations.

Paragraph	Requirement	First article	Conformance	Test/examination
3.3.1	Silver-silver chloride electrode element	☑	☑	4.5.1 and 4.5.7 to 4.5.10
3.3.2	Electrical connection	☑	☑	4.5.11
3.3.3	Assembly	☑		4.5.6, 4.5.12
3.4	Environmental performance requirements	☑	☑	4.5.2 to 4.5.5
NOTE: Performance B reference cells must pass environmental performance requirements (see 3.4) for both conformance and first article testing. Performance A reference cells must pass environmental performance requirements (see 3.4) for first article testing only.				

4.5 Test procedures.

4.5.1 Receiving. Upon receiving the test reference cells from the manufacturer, a non-destructive, visual inspection of the cable, assembly (if applicable), and reference element shall be preformed. Upon completion of testing, if necessary, a destructive examination shall be performed to inspect the integrity of the cell element.

4.5.1.1 Cable. The cable shall show no signs of damage or oxidation.

4.5.1.2 Assembly. The assembly shall show no signs of damage. All parts must be accounted for and in working, ready to install, order.

4.5.1.3 Reference element. The reference cell element should have a surface void of cracks or foreign matter.

4.5.2 Accuracy/offset/stability testing.

4.5.2.1 Reference cell standards. In Vivo Metric (IVM) Model E224N-P sintered silver-silver chloride (Ag/AgCl) reference cells, or equivalent as approved by NAVSEA, that have been correctly prepared for immersion service, shall be used as a standard cell to test product form cells both Performance A and B. A reference cell standard tank shall be provided to conduct the product form testing. The standard tank will consist of a separate tank from the Performance A or Performance B cell test tank and will contain 0.6N sodium chloride (NaCl) solution. The resistivity of the solution in the IVM tank shall be 18 ohm-centimeters ±1 ohm-centimeter. This resistivity will be checked regularly during all product form testing (minimum once weekly) and distilled water should be added, as necessary, to maintain the required resistivity. A minimum of 10 IVM cells, or equivalent, will be placed in the standard tank for 96 hours at room temperature to stabilize. All air bubbles shall be removed from the cell surface after immersion. At the end of the stabilization period, a DC voltage measurement will be conducted to record the voltage (potential) difference between nine of the cells, using the 10^{th} cell as the base cell to measure against. After completion of the measurement, three IVM or equivalent cells that measure within ±1 millivolt DC of each other verses the base cell shall be identified as standard cells and shall be used for further testing. One of the three cells will be used to compare all product form cells, called the base standard. The other cells will be maintained as spares in the event one of the standard cells fail.

4.5.2.2 Base standard reference cell failure. If the base standard IVM cell drifts more than ±1 millivolt DC from the initial differential reading between any of the other standard IVM cells, the base standard will be replaced by one of the other two Ag/AgCl standard cells as identified in 4.5.2.1.

4.5.2.3 Offset comparison test. The product form Performance A or Performance B cells shall be immersed in an appropriate sized test tank containing sufficient test electrolyte solution to cover the product form cells. The test electrolyte solution shall be comparable to natural seawater, with a resistivity of 18 ohm-centimeters, ±1 ohm-centimeter. The standard tank and the test tank shall be electrically connected via a salt bridge containing 0.6N NaCl solution (equivalent seawater conductivity). The product form cells should be allowed to stabilize for up to two weeks prior to environmental testing. During this stabilization period, the test tank electrolyte shall be changed out to new electrolyte on a daily basis. After stabilization, the differential DC voltage (potential) shall be measured between the Performance cells and the standard. The potential measurements shall be normalized to 20 °C as per the following equation:

$$E_{normalized} = E_{measured} + 0.33 \times \left(20 - T_{@\,E_{measured}}\right)$$

4.5.2.4 Stability. Stability refers to static noise, defined as the peak-to-peak differences in potential over a given period of time.

4.5.3 Static drift. Static drift is defined as the inherent deviation of potential versus standard from the initial value over a period of time in which there have been no environmental.

$$StaticDrift_n = E_{final} - E_{initial}$$

4.5.4 Temperature linearity testing.

4.5.4.1 Testing setup. Fill the test tank with seawater. Seawater shall not be changed for the duration of temperature cycling. Set the temperature bath or heating/cooling element to a temperature that will increase the temperature in the test tank to 90±3 °F. Once the temperature has reached a minimum of 90 °F, reverse the temperature control element to begin cooling. Cool until the temperature reaches a point below 40 °F. Once 40 °F has been reached, the temperature of the seawater in the test tank shall be brought back up to the initial starting temperature.

4.5.4.2 Recording/data analysis. DC Potential readings between the standard Ag/AgCl cell and each of the product form cells shall be recorded every five minutes and then graphed versus temperature. From the graphed data, a trend line shall be calculated and a slope derived.

4.5.5 Water resistivity linearity.

4.5.5.1 Testing setup. The reference electrodes shall be cycled through seawater solutions of varying resistivities. Target resistivities are 18±1, 36±2, 72±5, 144±10 and 288±20 ohm-centimeters. Solutions of varying amounts of seawater and fresh water shall be mixed to achieve the targeted resistivities.

4.5.5.2 Recording/data analysis. DC Potential readings between the standard Ag/AgCl cell and each of the product form cells shall be recorded and plotted for each resistivity level. This measure value shall be recorded at the same time index following the water change for each test solution resitivity and shall not be less than 24 hours. Potential readings should be graphed versus resistivity on semi log graph. From the graphed data a trend line shall be calculated and that a slope derived.

4.5.6 Pressure. Each sample electrode shall be mounted in a pressure test fixture so that the face and mating surface of the reference cell assembly shall be covered.

4.5.6.1 Application I reference cells. A pressure of 100±10 pounds/inches squared shall be applied to the base, electrode and pin assembly prior to assembly of the holder. The tube inserted over the electrode hub and O-rings shall be filled with a colored translucent liquid containing a wetting agent (i.e., Windex® or equivalent). The pressure shall be maintained for two minutes. No bubbles shall appear. Additionally no deformation should be present on the reference electrode or assembly.

4.5.6.2 Application II reference cells. Reference cell pressures are governed by ship specific criteria pertaining to test depth of the vessel. The tube inserted over the electrode hub and O-rings shall be filled with a colored translucent liquid containing a wetting agent (i.e., Windex® or equivalent). The pressure shall be maintained for two minutes. No bubbles shall appear. Additionally no deformation should be present on the reference electrode or assembly.

4.5.7 Chemical purity. Proper assessment of silver (Ag) and silver chloride (AgCl) purity shall be conducted. When specified (see 6.2), certification of this assessment shall be provided.

4.5.8 Cleaning. Cleaning is done by holding the mesh/plate in a reducing flame of a hydrogen gas burner for at least 30 seconds. The silver surface should be bright and shiny when removed from the flame. The silver shall be handled with stainless steel tongs to prevent contamination.

4.5.9 Surface area. Surface area of a plate style reference cell can be measured using a calibrated laboratory ruler. Proper surface area of a mesh style reference cell must be a mesh size of 40 or finer as illustrated in ASTM E11.

4.5.10 Service life. When specified (see 6.2), certification of thickness and longevity (life) calculations shall be provided to support service life requirements. The life will be based on the weight of AgCl used in the reference cell. Ensure that the minimum amount of AgCl on cell surface is no less than the value given by:

$$Weight_{AgCl}(mg) = \frac{3 \times LeakageCurrent(A) \times DesignLife(\sec)}{1.49}$$

Where the leakage current is given as the hull polarization value (e.g., 0.85 volt) divided by the input impedance of the potential measuring circuit (ohms). Note that the amount of AgCl on the reference cell face may typically be more than this value in order to ensure stable readings. The calculated value is only a minimum.

4.5.11 Underwater replacement. Test will require one reference cell assembly and one additional element. The manufactured assembly with original element will be placed in natural seawater for a period of two weeks. The reference cell voltage will be measured and logged verses a standard cell (see 4.5.2.1). After two weeks of exposure, the reference element will be replaced with a new element while underwater without removing the assembly from the test tank. The voltage will continue to be measured for an additional two weeks. At the end of this measurement period, the voltage difference measured must be within ±10 millivolts of the Performance A elements and ±4 millivolts of the standard for Performance B elements.

4.5.12 Shock testing. Shock testing will be accomplished in accordance with MIL-S-901. When specified (see 6.2), certification of test results shall be provided.

5. PACKAGING

5.1 Packaging. For acquisition purposes, the packaging requirements shall be as specified in the contract or order (see 6.2). When packaging of materiel is to be performed by DoD or in-house contractor personnel, these personnel need to contact the responsible packaging activity to ascertain packaging requirements. Packaging requirements are maintained by the Inventory Control Point's packaging activities within the Military Service or Defense Agency, or within the military service's system commands. Packaging data retrieval is available from the managing Military Department's or Defense Agency's automated packaging files, CD-ROM products, or by contacting the responsible packaging activity.

6. NOTES

6.1 Intended use. The reference electrodes are primarily intended for use in corrosion prevention in sea water of ship hulls, structures, sea chests, sonar domes and similar marine structures. The reference electrodes supply the central signal to the automatic control impressed current cathodic protection system.

6.2 Acquisition requirements. Acquisition documents should specify the following:

a. Title, number, and date of the specification.

b. When first article is required (see 3.1).

c. Requirements for rejected samples (see 4.3.4).

d. When certification of proper silver and silver chloride purity assessment must be provided (see 4.5.7).

e. When certification of thickness and longevity (life) calculations must be provided to support service life requirements (see 4.5.10).

f. When certification of shock test results must be provided (see 4.5.12).

g. Packaging requirements (see 5.1).

6.3 Subject term (key word) listing.

Control

Corrosion

Electrode

6.4 Changes from previous issue. Marginal notations are not used in this revision to identify changes with respect to the previous issue, due to the extensiveness of the changes.

Preparing Activity:
Navy – SH
(Project 2090-2008-022)

NOTE: The activities listed above were interested in this document as of the date of this document. Since organizations and responsibilities can change, you should verify the currency of the information above using the ASSIST Online database at http://assist.daps.dla.mil.