

CHAPTER 19 CATHODIC PROTECTION SYSTEMS

SECTION 1 - INTRODUCTION

19-1.1 PURPOSE

This chapter provides commands with the technical information and NAVSEA-approved procedures for the underwater maintenance of the hull-mounted components of ship fitted Impressed Current Cathodic Protection (ICCP) systems. Strict adherence to the contents of this chapter will provide the best assurance that all tasks are completed safely and efficiently.

19-1.2 SCOPE

The ICCP system is one of two equipment systems that use the principle of cathodic protection to combat the electrochemical effects of hull corrosion. The underwater maintenance of the other cathodic protection system, the Sacrificial Cathodic Protection system, is not addressed in this chapter. Underwater Ship Husbandry (UWSH) requires standardization of practices to ensure safe and cost-effective operations. This chapter provides NAVSEA-approved procedures and standardized instructions for the underwater inspection, cleaning and maintenance of ICCP system reference cells, anodes and dielectric shields. This chapter also provides detailed planning guidance for the installation of new reference cells, anodes, and dielectric shields. This chapter does not supersede information contained in the U.S. Navy Diving Manual or the Naval Ships' Technical Manual (NSTM).

19-1.2.1 This chapter is divided into four sections: an introduction to and description of the ICCP system, planning and preparation, inspection, and repair procedures.

19-1.3 APPLICABILITY

All personnel who are involved with the maintenance of the hull components of the ICCP system must be familiar with the appropriate sections of this chapter. This includes not only the fleet diving lockers, but also the ship- and shore-based maintenance activities responsible for the planning, implementation, and execution of maintenance for the ship-fitted ICCP system.

19-1.4 PRINCIPLES OF CATHODIC PROTECTION SYSTEMS

19-1.4.1 Theory of Corrosion. The term corrosion refers to the destruction of a metal or alloy by chemical or electrochemical reaction. Corrosion of a ship's metal hull below the waterline is predominantly electrochemical. Corrosion occurs when the conditions are present to form an electrochemical corrosion cell. These conditions are always present on the underwater portion of a ship's metal hull (see [Figure 19-1](#)). Variations in the chemistry of metal, both within the same hull metal and between dissimilar hull metals, lead to electropotential differences. Seawater, acting as the electrolyte, links these areas of differing electropotential, forming a corrosion cell.

The areas of the hull that are consumed electrochemically in the corrosion cell (releasing electrons to the seawater) are said to be anodic, and the areas of the hull where current reenters the hull are said to be cathodic. Hull corrosion occurs in those areas that are anodic.

19-1.4.2 The Galvanic Series. The rate at which the corrosion of a metal occurs depends to a large extent on the relative electropotentials of the two areas of metal linked in the corrosion cell. Within a given metal this difference is minimal. For dissimilar metals it is much greater. A measure of the electropotential differences between dissimilar metals is given in the Galvanic Series (see NSTM Chapter 633). In a corrosion cell, the metal with the greater negative electrical potential acts as the anode and will corrode.

19-1.4.3 The Principle of the Impressed Current Cathodic Protection System. Anodes strategically positioned on the hull emit an electrical current that suppresses current flow from the anodic areas of the hull, thereby rendering the entire hull cathodic and free from corrosion; hence the term Impressed Current Cathodic Protection (see [Figure 19-2](#)). The direct current produced by the power supply is provided to the anode by a conductor housed in a through-hull penetration. The anode is connected to the positive side of the power supply and the hull is connected to the negative side. Hull-mounted reference cells sense the electropotential of the hull which is passed to a power controller to regulate the power supply. The ICCP system continuously monitors and controls the current output to provide optimum corrosion protection. [Figure 19-3](#) shows the relationships of the individual ICCP units in a shipboard installation.

19-1.4.4 Anti-Corrosion Paint. The ICCP system is a secondary system of corrosion protection. The primary system is the ship's Anti-Corrosion (AC) system of corrosion protection. The AC paint coating acts as an inert barrier preventing the seawater and the hull link-up from forming a corrosion cell. When this protective barrier is breached (i.e. the paint is cracked, eroded, peeled or in some other way damaged), the ICCP system impresses a current into the areas of bare metal to render the metal cathodic and prevent corrosion.

19-1.4.5 Hull Areas Most Likely to Corrode. It is clear that the hull is most at risk in areas where dissimilar metals are found and areas where the paint system is most susceptible to damage. These conditions are found throughout the ship but are particularly evident around the stern tubes, shafts, propellers, rudders and the surrounding hull plate.

19-1.4.6 The Hull-Mounted Components of the ICCP System. The hull-mounted components of the ICCP system are:

a. Anodes. Anodes (see [Figure 19-4](#)) used in the ICCP system are constructed of a single continuous platinum-coated tantalum wire rod woven through an insulating glass-reinforced polyester holder. Each anode is bolted on the outside of the ship hull, and has a single hub which projects into the ship, connecting with the power supply through a gland assembly. Anodes are manufactured in 2-foot, 4-foot and 8-foot lengths. (The 2-foot anodes are not commonly used.) Typically, 4-foot anodes are found on smaller ships, such as the FFG and DDG classes, while the longer 8-foot anodes are found on the larger ships, such as the LHD and CV classes. The anodes are installed in sets along the hull. An anode set is comprised of two anodes of similar type located on opposite sides of the hull at the same frame number and distance above the baseline. A CV may have as many as 16 anodes on

each side of the hull. An FFG may have only 6 anodes. NSTM Chapter 633, "Cathodic Protection," provides the criteria for locating anodes on the hull. In general, they are located at the same depth, which must be greater than 5 feet below the light load line, in areas of minimum turbulence protected from mechanical damage, at least 15 feet from either a system intake or discharge.

CHANGE **b. Reference Cell.** The reference cell (see [Figure 19-5](#)) is an electrode constructed of a silver mesh screen that has been treated with silver chloride. It is mounted in a domed, 9-inch diameter circular polyvinyl chloride holder that electrically isolates the reference cell from the hull. The reference cell is secured to a base or sole plate by a pattern of screws. A series of holes in the reference cell permits passage of seawater at the hull, allowing the controller to detect electrochemical activity at the hull and measure the potential of the hull versus the reference electrode. The holes in the reference cell must remain open for the cell to function and should never be covered by paint or epoxy. Reference cells are installed approximately halfway between anodes powered by the same controller-power supply. One acts as a primary control, while the other serves as an auxiliary to verify operation of the primary cell, verify system operation on both sides of the hull, and provide primary service if the first cell fails.

c. Stuffing Tubes. Stuffing tubes are required for impressed current anodes and reference cells to establish through-hull watertight electrical connection of cables to pass current to the anodes and to pass voltage signals from the reference cells to the controller. Reference cell stuffing tubes are covered by MIL-S-23920. Anode stuffing tubes are not currently covered by a military specification. Stuffing tubes are supplied with reference cells and anodes as assemblies. If a stuffing tube penetrates into a fluid-filled compartment, such as a fuel tank, bilge, ballast tank or fresh water tank, the stuffing tube and the electrical cable leading to it must be enclosed in a protective cylindrical watertight cofferdam.

d. Dielectric Shield. The dielectric shield is a high-solids epoxy coating applied to the hull around each anode (see [Figure 19-6](#)). Dielectric shield areas have an inner shield area with a thickness of 100 mils minimum and a thinner outer shield area with a thickness of 22 mils minimum. For 4-foot anodes, inner shields extend to areas of 7 feet by 10 feet, and outer shields extend to areas 13 feet by 16 feet, as measured from the anode. For 8 foot anodes, inner shields extend to areas of 7 feet by 14 feet, and outer shields extend to areas 13 feet by 20 feet, as measured from the anode (see [Figure 19-6](#)). The dielectric shield prevents shorting of the anode current to the hull and aids in wider current distribution to the hull. Dielectric shield material is not covered by a military specification. The current NAVSEA-approved dielectric shield material is Capastic, provided by Engelhard Industries. Capastic, however, can only be applied in dry dock or in a dry chamber (cofferdam). There are underwater epoxies having excellent dielectric capability that can be applied in water to make repairs to damaged shields. [Appendix A](#) to this chapter provides a list of approved epoxies.

SECTION 2 - PLANNING AND PREPARATION

19-2.1 GENERAL INFORMATION

Planning is essential to the successful completion of any underwater ship husbandry task. Proper planning should begin at the earliest possible time, involve all concerned parties, and result in a written operational plan. General planning guidelines are presented in NAVSEA S0600-AA-PRO-020, General Information and Safety Precautions. While each ICCP maintenance task is unique, the requirements of the planning process are identical. The following paragraphs list the requirements that need to be considered. They should be viewed as impacting three resource areas: technical, personnel and organizational. The following paragraphs list the requirements that need to be considered. They should be viewed as impacting three resource areas: technical, personnel and organizational.

19-2.1.1 Isolation of the ICCP System. Commands planning ICCP system maintenance tasks must be aware that any break in the ICCP system will result in general corrosion with all its manifestations, even though most of the components may be completely capable of their functions. In general, the ICCP system should remain switched on whenever possible. Guidance for switching off the ICCP system to allow divers to work in the vicinity of ICCP hull fittings is detailed in the U.S. Navy Diving Manual and restated in the safety summary to this chapter. The prudent implementation of this policy will avoid the unnecessary replacement of defective ICCP hull-mounted fittings and reduce the risk of corrosion.

19-2.1.2 Identifying the Task. Components of an ICCP system may be defective for many reasons and the significance of a defect on the overall system effectiveness will vary. It may not be necessary to conduct any maintenance on a component that is clearly defective until the ship dry docks. It is important that the factors relating to a defect are clearly and fully understood; only then can the task be identified and the correct maintenance decision be taken. In this respect a thorough inspection (both internal and external) is vital. ICCP system inspections are addressed more fully in section 3.

19-2.2 REFERENCE DOCUMENTS

Technical information and engineering data essential to proper planning, preparation and execution of ICCP system anode, reference cell, and dielectric shield repairs/replacements are available in a variety of source documents. No single document provides all needed information. Care should be taken to obtain and use the most current version of source documents. They must be used during the planning phase and should be available on site during the conduct of the operation. NAVSEA S0600-AA-PRO-020 provides information on obtaining and using technical documents.

19-2.2.1 Ship Drawing Index. The Ship Drawing Index (SDI), maintained in the ship's log room or technical library, lists all the drawings applicable to that particular ship. Drawing numbers are arranged in the SDI by functional groups and they are numerically listed within these groups. The docking plan, shell expansion, and lines drawing may be of particular value.

19-2.2.2 ElectroCatalytic, Inc. is the sole provider of U.S. Navy ship fitted ICCP systems. Their address is: ElectroCatalytic, Inc., 2 Milltown Court, Union, NJ 07083. The following ElectroCatalytic drawings are available on request from NAVSEA 00C5 and are valuable when

planning and executing ICCP system repair and replacement:

- a. 72800, Installation drawing, Anode 2 ft.
- b. 36460-2L, Installation drawing, Anode 4 ft.
- c. 36460-2, Installation drawing, Anode 8 ft.
- d. 35754, Installation drawing, reference electrode assembly.

19-2.2.3 Technical Manuals. The Naval Ships' Technical Manual (NSTM) and other technical manuals provide operation and maintenance information, personnel qualifications, inspection criteria, technical and administrative information, and instructions to assist in managing ship systems and equipment. The technical manuals and other materials applicable for ICCP system repair and replacement are listed below:

- a. S9086-VF-STM-010, NSTM Chapter 633, "Cathodic Protection"
- b. NAVSEA S0600-AA-PRO-160, Underwater Ship Husbandry Manual, Chapter 16, Cofferdams
- c. NAVSEA S9086-CQ-STM-010, NSTM Chapter 081, "Waterborne Hull Cleaning of Navy Ships"
- d. NAVSEA S9086-VD-STM-020, NSTM Chapter 631 Volume 2, Preservation of Ships in Service - Surface Preparation and Painting.
- e. NAVSEA S9086-CH-STM-030, NSTM Chapter 074 Volume 3, "Gas Free Engineering"
- f. NAVSEA S0600-AA-PRO-170, Underwater Ship Husbandry Manual, Chapter 17, "Inspection Procedures"

19-2.2.4 Military Specifications and Standards.

- a. OPNAVINST 5100.19 (series), Navy Occupational Safety and Health (NAVOSH) Program Manual for Forces Afloat
- b. SSPC-SP-10, Steel Structures Paint Council, Visual Standards for Abrasive Blast Cleaned Steel
- c. MIL-E-23919, Electrodes, Reference, Circular, Corrosion Preventive
- d. MIL-S-24700, Stuffing Tubes for Reference Electrodes, Impressed Current Cathodic Protection

19-2.2.5 Records and Reports. The following records and reports, maintained in the ship's log room, often provide important information on ICCP system components:

- a. Underwater Repair/Working Reports.
- b. Ship Maintenance/Repair Records.
- c. Underwater Hull Inspection Reports.
- d. Underwater Hull Cleaning Reports.
- e. Diver Hull Inspection Data Sheet (NAVSEA Form 4730/7).

19-2.3 SHIP CHECK

A ship check is required to establish liaison with the ship's Engineering Officer and the work center with responsibility for the ICCP system. This allows the planner to retrieve information on conditions that may exist with the ICCP system or an associated system that could affect the success of the repair. The planner should conduct a thorough internal inspection of the repair area for material condition, ease of access, and interference. If the compartment in which the anode or reference cell gland assembly is located is an enclosed compartment, consideration must be given to the requirement of obtaining gas-free access in accordance with NSTM 074 Volume 3, Section 20. In ballast and fuel tanks in particular, temporary scaffolding and lighting may be required. In all situations, portable communications must be established between personnel working at the hull penetration, the dive supervisor, and, if appropriate, a safety sentry who will be positioned at the entrance to the enclosed compartment. An external inspection is required to determine accessibility to the repair area, positioning of the ship and the availability of work area.

19-2.4 INSPECTION DIVE

A thorough inspection dive must be conducted in advance of the repair task. The dive should identify precisely the nature of the reported defect so that a proper assessment of the required maintenance can be developed. Section 3 covers this matter in more detail. The dive should also ascertain conditions at the underwater work site. This is particularly important if the resulting repair may require the use of a habitat. Detailed planning considerations for the use of habitats in support of UWSH are given in NAVSEA S0600-AA-PRO-160, Cofferdams.

19-2.5 CHOOSING THE APPROPRIATE ANODE REPLACEMENT PROCEDURE

19-2.5.1 There are two anode replacement procedures: a dry procedure and a wet procedure. The choice as to which is the most appropriate procedure is governed largely by the dielectric epoxy that is used to fair in the new anode.

19-2.5.2 The dry procedure uses a habitat to enclose the anode, creating a dry environment

that permits the use of the epoxy Capastic. The wet procedure does not use a habitat. This precludes the use of Capastic and demands the use of an approved underwater epoxy (see [Appendix A](#)).

19-2.5.3 The dry procedure is more costly in both time and expense. The templating, construction, and fitting of the habitat combined with the requirement to maintain a dry environment for the Capastic epoxy to cure, adds approximately 48 hours to the repair task. The disadvantage of the wet procedure is the sensitivity of the underwater epoxy. It must be mixed exactly and the underlying hull prepared precisely. The epoxy, which is difficult to apply, must be adhered to the hull during a very narrow time window between epoxy mixing and hull preparation. Furthermore, underwater epoxy is unlikely to be applied successfully if the ambient temperature is below 50° F. In contrast, successful application of the epoxy Capastic is relatively easy and both cure times and the ease of application are independent of ambient temperature.

19-2.6 TYPICAL REPAIR TASK DURATION

- a. Anodes. Wet Procedure: One anode can be replaced in 2-3 days, dependent on environmental conditions, i.e. epoxy cure times. Dry Procedure: One anode takes 4-5 days.
- b. Reference Cells. One or two reference cells can be replaced in 2 days.
- c. Dielectric Shield Repair. Dependent on the extent of damage.

19-2.7 TOOLS, MATERIALS, AND EQUIPMENT REQUIREMENTS

CAUTION
It is essential that all tools and materials brought to the underwater job site are accounted for and removed at the completion of the job. Tools and materials inadvertently left at the job site can generate unacceptable noise and possibly cause severe damage to shipboard components. Locally generated work packages shall ensure that a general tool and material log sheet is prepared and maintained during all UWSH operations.

Removal and replacement of ICCP system anodes and reference cells and repairs to dielectric shields require the use of tools, materials, and equipment which should be made available in advance. [Table 19-1](#) (in section 4) provides a listing of the tools, materials, and equipment required for anode replacement. [Table 19-2](#) provides the same for reference cell replacement. [Table 19-3](#) provides the same for dielectric shield repair.

SECTION 3 - INSPECTION

19-3.1 GENERAL

Diver inspection of the hull-mounted components of the ICCP system, reference cells, anodes, and dielectric shields is an essential component of the condition-based maintenance of the ICCP system.

19-3.1.1 Regular diver inspections will be conducted when a vessel receives a programmed hull cleaning and on occasions when a systemic failure or other problem indicates a condition that requires underwater examination of the ICCP system.

19-3.1.2 The inspection dive can only be successful if the diver knows what to look for and understands the significance of the findings. A thorough pre-dive brief by a competent person is essential. This should include the relevant information distilled from: (i) a review of the last inspection report (recorded on a Diver Hull Inspection Data Sheet NAVSEA Form 4730/7 ([Figure 19-7](#))), which will provide a bench mark for system condition, and (ii) a brief from the ship's work center responsible for the ICCP system identifying any known problems.

19-3.1.3 Results from the inspection dive must be recorded on a Divers Hull Inspection Data Sheet NAVSEA Form 4730/7 and if appropriate supplemented by video or still photography. The form should be completed and, along with supporting data, forwarded to the activity requesting the inspection, with a copy for the ship. On occasion the report will indicate that maintenance is required, such as dielectric shield, anode, or reference cell cleaning; dielectric shield repair; or anode and reference cell replacement. Technical guidance to support a proposed maintenance plan can be obtained from Fleet Technical Support Center, Atlantic, 9280 10th Avenue, Norfolk, VA 23511-4396; Fleet Technical Support Center, Pacific, Box 85548, San Diego, CA 92186-5540; or Naval Sea Systems Command (SEA 03M or SEA 00C5). In such cases all of the above inspection data, along with the relevant data from the ship's cathodic protection log (NAVSEA Form 9633/1) and any other relevant data must be made available to the above technical authorities.

19-3.2 INSPECTION PROCEDURES

Procedures for conducting an underwater ship husbandry inspection are provided in NAVSEA S0600-AA-PRO-170, Underwater Ship Husbandry Manual, Chapter 17. The following paragraphs provide supplementary details. [Figure 19-7](#) is an example of NAVSEA Form 4730/7 that is used to record the results of all inspection dives on the ICCP system. A separate sheet of Form 4730/7 shall be used for each anode/shield inspected.

19-3.2.1 Inspection Dive Considerations. The following are the factors and considerations that support the requirements of the Divers Hull inspection data sheet. A review of these considerations will help focus the inspection dive.

a. ICCP System Redundancy. Many ship-fitted ICCP systems are designed with a degree of redundancy. By design there are more anodes than are necessary to

provide full cathodic protection. The importance of the ICCP system is as a backup to the anti-corrosion (AC) paint scheme. It protects the ship's hull from the corrosion cell that could form in the event of a failure of the paint scheme. In the free-flood areas both of these conditions are likely to be found.

b. Anode Location. Paragraph a. above makes it essential that the location of the anode and the condition of the paint scheme are accurately recorded during an inspection.

c. Anode Redundancy. Each anode has a degree of redundancy built in. If less than 25 percent of the platinum coated tantalum wires are broken, the anode can still function satisfactorily. Similarly, up to 25 percent of each coating of platinum can be missing and each platinum anode will still function correctly.

d. Position of Broken Anode Wires. Because each anode wire is a single continuous loop running from the center of the anode to the outer edges, and power to the anode comes from the center, a break in the wire becomes progressively more significant the closer it is to the center.

Points c. and d. make it essential that the position of a damaged wire and the total percentage of platinum coating damage are recorded.

e. Discoloration in The Dielectric Shield. The dielectric shield varies in color. The dielectric epoxy, Capastic, is gray. If the shield has been repaired underwater it may be another color (such as black). The overlying paint scheme can be many colors and the area of the dielectric shield above and to the stern of the anode may appear bleached (a product of the caustic water chemistry created by the anode's operation).

19-3.2.1.1 All of these patterns and color variations are normal. In the past they have been reported, erroneously, as evidence of electrical burning.

19-3.2.2 Anode and Dielectric Shield Inspection.

a. Begin the inspection procedure by conducting a cursory inspection of the anode, dielectric shield and the immediate hull out to a distance of 20 feet. Identify obvious damage and assess the overall condition of the system. Record how long the anode has been electrically isolated, i.e. de-energized.

b. Conduct a detailed inspection of the anode.

(1) Record the Fouling Rating (FR), its nature (soft or hard calcareous, soft or hard marine fouling), and any differential fouling (such as fouling just on the epoxy filler above the anode retaining nuts, or just on the tantalum wires).

(2) Inspect the tantalum wires:

(a) Ensure that all wires are present and count them.

(b) If wires are damaged (missing, broken, or bent), provide the following details: position of the wire relative to the center of the anode and if the damage is in that portion of the wire that is coated with platinum.

(3) Inspect the platinum coating on each wire:

(a) Ensure that none of the coating is missing.

(b) Ensure that the coating is tightly bonded to the wire.

(c) Check for discoloration, peeling, or bonding. Report all defects as a percentage of the total platinum coating.

(4) Inspect the glass-reinforced polyester holder:

(a) Check for damage, chips, dents, cracks or erosion and report the position relative to the center of the anode.

(b) Confirm that the plugs of epoxy that cover the anode retaining nuts/bolts are secure and undamaged.

c. Conduct a detailed inspection of the Dielectric Shield.

(1) Dielectric Shield - Anode Interface. This is the most critical area of the dielectric shield. Examine the area closely.

(a) Check that the dielectric shield is evenly faired up to the top flat face of the anode.

(b) Confirm that a solid bond exists between the dielectric shield and the anode holder.

(c) Check for cracks/chips or other signs of damage in the dielectric shield.

(2) Dielectric Shield

(a) Record the location of all defects in the outer and inner shield.

- (b) Describe as either cracks, isolated pits/patches, flaking, or eroded, full or partial penetration.
- (c) Record the dimensions of each defect: total area, width and length.
- (d) Describe the pattern of cracks: radiating from the anode, circumferential or irregular.
- (e) Record the location of all fouling in the outer and inner shield (FR).
- (f) Describe as either hard or soft calcareous fouling or hard or soft marine growth.
- (g) Record the dimensions of all growth.

SECTION 4 - REPAIRS

19-4.1 INTRODUCTION

Divers are able to perform the following maintenance tasks on the hull-mounted components of the ICCP system:

- a. Anode Replacement: Depending on the particular conditions of the task, this may be conducted either with a habitat, using the dry procedure, or without a habitat, using the wet procedure.
- b. Reference Cell Replacement
- c. Dielectric Shield Repair

19-4.1.1 The detailed procedure for each of these repairs is included in this section.

NOTE

While the following procedures require topside, Ship's Force, and divers to work closely together, certain steps must be carried out by particular personnel. To clarify these steps, abbreviations are placed at the beginning of each step where the specific party needs to be identified: (DV) represents diver, (TOP) represents topside personnel, and (SF) represents Ship's Force personnel.

19-4.2 ANODE REMOVAL AND REPLACEMENT PROCEDURE - DRY

19-4.2.1 Anode Removal

WARNING

Underwater electrical equipment must be secured while divers are working over the side. Hull deterioration is most severe while the ICCP system is de-energized and the effects are irreversible. The appropriate zone of the ship's ICCP system must be secured, tagged out, and confirmed secured before divers may work on an ICCP device (anode, dielectric shield, or reference cell). When divers are required to work in close proximity to an active ICCP anode and risk of contact with an anode exists, that part of the system must be secured for the duration of the repair. In other than these situations the ICCP system is to remain active. Divers working within 15 feet of an active system must wear a full dry suit, unisuit, or wet suit with hood and gloves. Clear communications among divers, surface personnel, and inboard Ship's Force personnel are crucial for safe and effective coordination of tasks and the maintenance of watertight integrity at through-hull penetration sites.

19-4.2.1.1 The activity conducting the anode removal and replacement shall:

- a. Ensure all required materials are on hand using [Table 19-1](#) for guidance.
- b. Coordinate material, technical, and funding requirements.
- c. Conduct anode replacement training in accordance with Naval Ships' Technical Manual, S9086-VF-STM-010/CH-633, "Cathodic Protection."
- d. Arrange with the ship for control and disposal of hazardous material.
- e. Prepare video and still cameras to document work throughout the procedure. Notify ship of any special precautions required in the performance of removal/replacement.

19-4.2.1.2 The Ship's Force shall:

- a. Ensure that the ship is moored with the affected anode toward the pier.
- b. Tag out equipment and systems for conduct of diving operations.
- c. Control and dispose of hazardous materials as agreed with the performing activity.

19-4.2.1.3 (SF) Defuel and gas free the compartment / tank space in which the anode hull penetration is located, and other compartments as necessary to access the anode connection box.

19-4.2.1.4 (SF) Rig lighting, and establish ladders and scaffolding as necessary to access the anode.

19-4.2.1.5 (SF) If the anode hull penetration is in an enclosed compartment, provide a sentry in the nearest lit, ventilated compartment who is able to maintain verbal contact with working personnel, especially if they are in an enclosed compartment.

19-4.2.1.6 (SF) Verify that the appropriate zone of the ICCP system has been de-energized and tagged out. The rest of the ICCP system should remain energized.

NOTE

The de-energized zone will remain de-energized and tagged out until the epoxy is cured.

19-4.2.1.7 (SF, TOP, DV) Establish communications between the inboard side of the anode hull penetration (Ship's Force sentry), the dive supervisor, and the divers.

NOTE

The dive supervisor must be satisfied that the preparatory steps [19-4.2.1.3](#) through [19-4.2.1.7](#) have been completed before proceeding.

NOTE

Templating of the hull, top section construction, rigging and placement of the habitat should be done as early in the procedure as possible, independent of the internal Ship's Force actions. Guidance for this task is provided in NAVSEA 0600-AA-PRO-016, Underwater Ship Husbandry Manual, [Chapter 16, "Cofferdams."](#)

NOTE

Items listed in the following steps refer to the anode assembly shown in [Figure 19-8](#) and the associated Electrochemical Anode installation drawing detailed in [19-2.2.2](#).

NOTE

The actions in [paragraphs 19-4.2.1.8](#) through [19-4.2.1.10](#) are required only if the anode connection box is located within a tank or void space.

19-4.2.1.8 (SF) Remove the cover plate of the anode cell high-hat cofferdam.

19-4.2.1.9 (SF) Remove and inspect the high-hat cofferdam gasket. Replace the gasket if necessary.

19-4.2.1.10 (SF) Inspect the inside of the high-hat cofferdam for signs of corrosion or seepage of fuel or water. If there are such signs, determine the cause and if possible, rectify the defect.

NOTE

If the problem of liquid seepage into the cofferdam can not be corrected, Ship's Force should be notified and a decision made whether or not to continue with the anode replacement. If the root cause of a defective anode can not be corrected, replacement of the anode is of questionable value.

19-4.2.1.11 (SF) Ensure the ship is tagged out for diving.

19-4.2.1.12 (SF) Remove the electrical connection box cover.

CHANGE **19-4.2.1.13** (SF) Using a scribe or flat blade screwdriver, carefully remove the paraffin from inside of the electrical connection box, if present. Using a forced hot air blower, melt the remaining traces of paraffin to assist in its removal. Remove the nut, lock washer and disconnect the terminal lug. Then remove the electrical cable, flat washer, second nut, flat washer and insulating washer.

19-4.2.1.14 (SF) Remove the connection box.

19-4.2.1.15 (SF) Remove the gland gasket.

19-4.2.1.16 (SF) Remove the packing nut using a 1 3/8-inch socket wrench

19-4.2.1.17 (SF) Remove the female prong assembly.

19-4.2.1.18 (SF) Remove the truarc ring.

19-4.2.1.19 (SF) Remove the packing nut.

NOTE

The Teflon packing rings can not be removed at this stage because of the restrictive force of the anode hub.

19-4.2.1.20 (SF) Inspect the internal bore of the anode gland for corrosion and roughness. Clean as necessary. Coat the anode gland body with silicone grease.

CHANGE **19-4.2.1.21** (SF) Fit the anode gland assembly internal blanking plug ([Figure 19-9](#)). Open and shut the vent valve of the blanking plug.

19-4.2.1.22 (TOP, DV) Rig and lower the habitat template to the hull and adjust dowels to fit the anode location site. Return template to the surface and use measurements taken to construct the top section of the habitat.

19-4.2.1.23 (TOP, DV) Rig and lower the completed habitat to the hull and secure. De-water the habitat to create a dry environment.

19-4.2.1.24 (DV) Remove the fairing epoxy from the anode securing nuts, using a hammer and chisel. Two-foot anodes have four mounting holes for the threaded weld studs and securing hex nuts. Four-foot anodes have 8 mounting holes for the threaded weld studs and securing hex nuts. Eight-foot anodes have 16 mounting holes for studs, nuts, and washers.

19-4.2.1.25 (DV) Working from the center outward, loosen hex nuts, one turn at a time.

19-4.2.1.26 (DV) Completely remove all hex nuts and washers.

CAUTION

Removal of the anode requires removal of at least some of the dielectric shield around the anode. Great care should be taken to avoid cracking or otherwise damaging the existing shield. Additional shield damage will require removal and subsequent additional application of epoxy.

19-4.2.1.27 (DV) Using the right angle hydraulic grinder, grind out a band approximately 2 inches wide from the dielectric shield around the anode. If the dielectric shield has been damaged or is delaminating, it may be necessary to remove a wider band. It is important that the remaining shield present a well bonded surface to which the new epoxy can be married.

NOTE

Four-foot anodes weigh approximately 20 pounds. Eight-foot anodes weigh approximately 30 pounds. Both can be moved underwater by divers without additional lifting equipment.

19-4.2.1.28 (DV) Using wooden wedges as appropriate, remove the anode from the hull. Recover the anode to the surface.

19-4.2.1.29 (DV) Pass the anode to the divers for transport to the habitat. Fit the anode loosely over the studs to ensure it fits correctly. If it does not, mark the top of the anode where it rubs and return it to the surface. If necessary, carefully file away the minimum amount of ceramic necessary to fit the anode over the studs. (See [Figure 19-8](#).) On completion, make sure that the washers on the studs still provide adequate overlap on the enlarged hole.

19-4.2.1.30 (DV) Fit and secure the external anode gland assembly blanking plate. (See [Figure 19-10](#).) Locating the predrilled holes of the blanking plate over the two studs on either side of the anode hull penetration, fit a nut to each stud and tighten with a torque wrench to 10 ft.-lbs.

CAUTION

The exposed anode securing studs are used to mount the replacement anode and must not be damaged during sandblasting or repair of the dielectric shield.

19-4.2.1.31 (DV) Thread two nuts on each of the exposed anode securing studs. The nuts will protect the stud threads.

CHANGE **19-4.2.1.32** (SF) Remove the internal blanking plug.

19-4.2.1.33 (SF) Noting both the number and original fitted order, remove the old Teflon rings with a right-angled or hook scribe.

19-4.2.1.34 (SF) Clean the anode gland using clean dry rags, and if necessary, a handheld forced air blower.

19-4.2.1.35 (SF) The packing rings come taped together. Remove the plastic tape holding the Teflon packing rings and apply a layer of silicone grease to the outside and inside surfaces of the rings. Do not change the arrangement of the rings from the order in which they were originally taped. Insert all the packing at once into the body of the gland. The thick square end ring is placed inboard and the thin square ring is outboard.

19-4.2.1.36 (SF) Insert the packing nut into the gland and tighten until the nut just touches, but does not compress, the Teflon packing.

CHARGE **19-4.2.1.37** (SF) Refit the anode gland internal blanking plug and close the vent valve.

19-4.2.1.38 (DV) Remove the external blanking plate and fit two protection nuts to each of the anode studs adjacent to the hull penetration. Fit a presoaked DC plug, for secondary protection, into the anode gland.

CAUTION
Operators of sandblasting equipment must be familiar with and observe the Warnings and Cautions contained in [Appendix B](#) to this chapter.

CAUTION
Divers must wear protective headgear and breathing apparatus while sandblasting inside the habitat.

19-4.2.1.39 (DV) Prepare the exposed hull area to receive the replacement anode by sandblasting the bare metal to a near-white metal finish in accordance with SSPC-SP-10.

NOTE
Capastic epoxy bonds most effectively to a slightly uneven (roughened) surface. A sandblasted surface is ideal. The edge of the dielectric shield should be faired by the sandblaster to a 20-30 degree angle to receive the epoxy.

19-4.2.1.40 (DV) Sandblast the edge of the existing dielectric shield to create a surface suitable for subsequent fairing in of the Capastic epoxy.

19-4.2.2 Anode Replacement

NOTE

Apply duct tape layers in patterns that both protect and are easy to remove.

19-4.2.2.1 (TOP) Using duct tape, apply a protective layer of strips sufficient to cover the outboard side of the replacement anode. This will keep epoxy from fouling the anode surfaces. Carefully cut out holes in the tape layer corresponding to the anode securing holes. The anode surface must be protected from epoxy fouling but must also provide accessibility to the securing studs. Fit a protective cover of duct tape over the male probe extending from the anode hub.

CAUTION

Epoxies, paints, and solvents are toxic and can cause serious injury to eyes and skin. Wear protective goggles, coveralls, and impervious rubber gloves during mixing and application. Epoxies, paints, and solvents emit toxic fumes. Ensure adequate ventilation for personnel during mixing, application, or cleanup of toxic materials.

19-4.2.2.2 (TOP) Cement the neoprene mat to the anode by applying a layer of silicone rubber cement to one mat side and carefully laying that side onto the anode, carefully guiding the anode hub through the mat hub hole. Ensure that the anode hub is not damaged, and the mat holes are aligned with the anode stud holes. The neoprene mat will not completely cover the anode, and there will be an outer margin around the mat where the anode is exposed. Apply a layer of silicone rubber cement around the edge of the neoprene mat hull side, making sure not to plug the aligned stud holes.

19-4.2.2.3 (TOP) Apply a layer of Capastic epoxy to the exposed margin of the anode around the mat, building up this margin to the same height as the neoprene mat. The Capastic should form a frame around and flush with the neoprene mat.

19-4.2.2.4 (DV) Remove the nuts protecting the anode securing studs. Remove the pre-soaked DC plug from the anode gland hull penetration.

19-4.2.2.5 (TOP, DV) Place the prepared replacement anode into two watertight plastic bags, and pass the anode to the divers for transport into the habitat.

CAUTION

Epoxies, paints, and solvents are toxic and can cause serious injury to eyes and skin. Wear protective goggles, coveralls, and impervious rubber gloves during mixing and application. Epoxies, paints, and solvents emit toxic fumes. Ensure adequate ventilation for personnel during mixing, application, or cleanup of toxic materials.

19-4.2.2.6 (DV) Remove the prepared anode from the plastic bags. Remove the duct tape covering the male probe extending from the anode hub. Carefully locate the anode over the securing studs so that the anode hub projects into the anode gland hull penetration, and the securing studs project through the anode stud holes.

CAUTION

Uneven or extreme tightening of securing bolts will shatter the ceramic surface of the anode.

19-4.2.2.7 (DV) Place a washer and hex nut on each securing stud to hold the anode and, starting from the centermost studs, tighten each nut using only moderate torque. Tighten all nuts evenly, waiting several minutes between successive tightenings to permit the Capastic to squeeze against the prepared hull surface and flow out from the back of the anode. Tighten all nuts to a torque of 10 ft.-lbs.

CAUTION

The careful application and successful bonding of Capastic epoxy is crucial to the repair.

19-4.2.2.8 (DV) Press the squeezed Capastic epoxy around the anode evenly, fairing in the anode and marrying the epoxy to the clean, roughened existing dielectric shield edge. Cover all metal hull areas. Add additional Capastic as necessary to completely fill and fair the gap between the old shield and the replacement anode. Evenly fill in any irregular or trimmed areas of dielectric shield so that the integrity of the shield is completely restored.

19-4.2.2.9 (DV) Apply Capastic epoxy to fill the securing nut holes in the tape layer above the anode securing nuts, fairing the epoxy to the upper surface of the anode. When all epoxy has been applied, carefully remove the duct tape from the anode. All epoxy must now cure for 24 hours before being exposed to water.

CHANGE **19-4.2.2.10** (SF) Vent and remove the internal blanking plug.

CAUTION

Do not tighten the packing nut down onto the top of the anode hub. If the correct number of packing rings have been fitted properly, this should not be possible.

NOTE

When Teflon is compressed it will creep, i.e. slowly distort and flow away from the compressive force. The Teflon packing rings are the primary watertight seal. To ensure that the Teflon rings form an effective watertight seal it is essential that the gland nut compressing the Teflon rings is retightened 24 hours after the initial compression.

19-4.2.2.11 (SF) Tighten the packing nut with a 1 3/8-inch socket wrench until the packing is compressed to the limit. Retighten at intervals until tight and the Teflon has crept as far as possible. Repeat the operation one hour later and 24 hours later.

19-4.2.2.12 (SF) Assemble two O-rings to the female prong assembly. Lubricate the female prong assembly and O-rings with silicone grease.

19-4.2.2.13 (SF) Install the truarc ring, female prong assembly and packing nut, then tighten down the packing nut.

19-4.2.2.14 (SF) Install the gland gasket and the connection box.

19-4.2.2.15 (SF) Install the insulating washers, washer, nut, washer, anode cable lug (with cable), lock washer, and nut.

19-4.2.2.16 (SF) Install the gasket for the connection box cover and the connection box cover.

19-4.2.2.17 (SF) For protection against water, hull penetrations may have connection boxes fitted with a fill hole. Fill the connection box with paraffin. Insert the pipe plug in the tapped fill hole.

19-4.2.2.18 (SF) Replace the high-hat cofferdam cover (if in a void or tank).

CAUTION

Capastic epoxy must be fully cured before the ICCP system is tested.

19-4.2.2.19 (DV) Enter the habitat after the 24 hour Capastic cure period, and visually inspect the epoxy applications. Confirm that the epoxy has cured and appears properly bonded to the existing dielectric shield.

19-4.2.2.20 (DV) When the Capastic cure has been confirmed, the habitat must be flooded for ICCP system testing, but not removed in case further repairs are necessary.

19-4.2.2.21 (SF) Energize the ICCP system to assure the proper operation of the replacement anode. Procedures for inspection and adjustment of system operation following shutdown and testing replacement anodes are provided in NSTM 633, Section 6.

19-4.2.2.22 (SF, DV) When proper ICCP system operation is confirmed, unrig the habitat from the hull and rerig to the crane for retrieval from the water. Photograph the final repair. Remove the ship tag out for the ICCP system.

19-4.3 ANODE REMOVAL AND REPLACEMENT PROCEDURE - WET

19-4.3.1 Anode Removal

WARNING

Underwater electrical equipment must be secured while divers are working over the side. Hull deterioration is most severe while the ICCP system is de-energized and the effects are irreversible. The appropriate zone of the ship's ICCP system must be secured, tagged out, and confirmed secured before divers may work on an ICCP device (anode, dielectric shield, or reference cell). When divers are required to work in close proximity to an active ICCP anode and risk of contact with an anode exists, that part of the system must be secured for the duration of the repair. In other than these situations the ICCP system is to remain active. Divers working within 15 feet of an active system must wear a full dry suit, unisuit, or wet suit with hood and gloves. Clear communications among divers, surface personnel, and inboard Ship's Force personnel are crucial for safe and effective coordination of tasks and the maintenance of watertight integrity at through-hull penetration sites.

19-4.3.1.1 The activity conducting the anode removal and replacement shall:

- a. Ensure all required materials are on hand using [Table 19-1](#) for guidance.

- b. Coordinate material, technical, and funding requirements.
- c. Conduct anode replacement training in accordance with Naval Ships' Technical Manual, S9086-VF-STM-010/CH-633, "Cathodic Protection."
- d. Arrange with the ship for control and disposal of hazardous material.
- e. Prepare video and still cameras to document work throughout the procedure. Notify ship of any special precautions required in the performance of removal/replacement.

19-4.3.1.2 The Ship's Force shall:

- a. Ensure that the ship is moored with the affected anode toward the pier.
- b. Tag out equipment and systems for conduct of diving operations.
- c. Control and dispose of hazardous materials as agreed with the performing activity.

19-4.3.1.3 (SF) Defuel and gas free the compartment/tank space in which the anode hull penetration is located, and other compartments as necessary to access the anode connection box.

19-4.3.1.4 (SF) Rig lighting and establish ladders as necessary to access the anode.

19-4.3.1.5 (SF) If the anode hull penetration is in an enclosed compartment, provide a sentry in the nearest lit, ventilated compartment who is able to maintain verbal contact with working personnel, especially if they are in an enclosed compartment.

19-4.3.1.6 (SF) Verify that the appropriate zone of the ICCP system has been de-energized and tagged out. The rest of the ICCP system should remain energized, ionizing the hull which improves the adhesion of aquatic epoxy resins

19-4.3.1.7 (SF, TOP, DV) Establish communications between the inboard side of the anode hull penetration (Ship's Force sentry), the dive supervisor, and the divers.

NOTE

The dive supervisor must be satisfied that preparatory [steps 19-4.3.1.3](#) through [19-4.3.1.7](#) have been completed before proceeding.

NOTE

The actions in [paragraphs 19-4.3.1.8](#) through [19-4.3.1.10](#) are required only if the anode connection box is located within a tank or void space.

CHANGE **19-4.3.1.8** (SF) Remove the cover plate of the anode high-hat cofferdam. ([Figure 19-12](#))

19-4.3.1.9 (SF) Remove and inspect the high-hat cofferdam gasket. Replace the gasket if necessary.

19-4.3.1.10 (SF) Inspect the inside of the high-hat cofferdam for signs of corrosion or seepage of fuel or water. If there are such signs, determine the cause and if possible, rectify the defect.

NOTE

If the problem of liquid seepage into the cofferdam cannot be corrected, Ship's Force should be notified and a decision made whether or not to continue with the anode replacement. If the root cause of a defective anode can not be corrected, replacement of the anode is of questionable value.

19-4.3.1.11 (SF) Ensure the ship is tagged out for diving.

19-4.3.1.12 (SF) Remove the electrical connection box cover.

CHANGE **19-4.3.1.13** (SF) Using a scribe or flat blade screwdriver, carefully remove the paraffin from inside of the electrical connection box, if present. Using a forced hot air blower, melt the remaining traces of paraffin to assist in its removal. Remove the nut, lock washer and disconnect the terminal lug. Then remove the electrical cable, flat washer, second nut, flat washer and insulating washer.

19-4.3.1.14 (SF) Remove the connection box.

19-4.3.1.15 (SF) Remove the gland gasket.

19-4.3.1.16 (SF) Remove the packing nut using a 1 3/8-inch socket wrench.

19-4.3.1.17 (SF) Remove the female prong assembly.

19-4.3.1.18 (SF) Remove the truarc ring.

19-4.3.1.19 (SF) Remove the packing nut.**NOTE**

The Teflon packing rings can not be removed at this stage because of the restrictive force of the anode hub.

19-4.3.1.20 (SF) Inspect the internal bore of the anode gland for corrosion and roughness. Clean as necessary. Coat the anode gland body with silicone grease.

CHANGE **19-4.3.1.21** (SF) Fit the anode gland assembly internal blanking plug ([Figure 19-9](#)). Open and shut the vent valve of the blanking plug.

CHANGE CAUTION

Great care should be taken to avoid damaging the securing studs.

19-4.3.1.22 (DV) Remove the fairing epoxy from the anode securing nuts, using a hammer and chisel. Two-foot anodes have 4 mounting holes and securing nuts. Four-foot anodes have 8 mounting holes and securing nuts, while eight foot anodes have 16-mounting holes and securing hex nuts.

CAUTION

Removal of the anode requires removal of at least some of the dielectric shield around the anode. Great care should be taken to avoid cracking or otherwise damaging the existing shield. Additional shield damage will require removal and subsequent additional application of epoxy.

CHANGE CAUTION

Extreme care should be taken to avoid grinding, chiseling, or cutting into the underlying hull plating during the epoxy removal process.

CHANGE **19-4.3.1.23** (DV) Using a hydraulic grinder, grind out a band approximately 2 inches wide from the dielectric shield around the anode. First make a perimeter grind around the anode at the 2-inch distance ([Figure 19-10A](#)). Then grind a cross pattern around the perimeter. Using a pneumatic hammer chisel remove the 2-inch band of epoxy around the anode. If the dielectric shield has been damaged or is delaminating, it may be necessary to remove a wider band. It is

important that the remaining shield present a well bonded surface to which the new epoxy can be married.

NOTE

Four-foot anodes weigh approximately 20 pounds. Eight-foot anodes weigh approximately 30 pounds. Both can be moved underwater by divers without additional lifting equipment.

19-4.3.1.24 (DV) Using wooden wedges as appropriate, remove the anode from the hull. Transfer the anode to the surface.

19-4.3.1.25 (DV) Fit and secure the external anode gland assembly blanking plate ([Figure 19-10](#)). Locating the predrilled holes of the blanking plate over the two studs to either side of the anode hull penetration, fit a nut to each stud and tighten with a torque wrench to a torque of 10 ft.-lbs.

CAUTION

The exposed anode securing studs are used to mount the replacement anode, and must not be damaged during sandblasting or repair of the dielectric shield.

19-4.3.1.26 (DV) Thread two nuts on each of the exposed anode securing studs. The nuts will protect the stud threads.

19-4.3.1.27 (SF) Open the vent valve on the anode gland internal blanking plug. Seawater which entered the stuffing tube when the anode was removed may be present, but it is important to confirm that there is no leak of seawater from the external blanking plate. When this has been confirmed, close the valve and remove the blanking plate. Evacuate any water in the gland body.

19-4.3.1.28 (SF) Noting both the number and original fitted order, remove the old Teflon rings with a right-angled or hook scribe.

19-4.3.1.29 (SF) Clean the anode gland using clean dry rags, and if necessary a hand-held forced air blower.

19-4.3.1.30 (SF) Remove the plastic tape holding the Teflon packing rings and apply a layer of silicone grease to the outside and inside surfaces of the rings. Do not change the arrangement of the rings from the order in which they were originally taped. Insert all the packing at once into the body of the gland. The thick square end ring is placed inboard and the thin square ring is outboard.

19-4.3.1.31 (SF) Insert the packing nut into the gland and tighten until the nut just touches, but does not compress, the Teflon packing.

19-4.3.1.32 (SF) Refit the anode gland internal blanking plug and close the vent valve.

19-4.3.1.33 (DV) Remove the external blanking plate and fit two protection nuts to each of the anode studs adjacent to the hull penetration.

19-4.3.1.34 (DV) Fit a pre-soaked DC plug into the anode gland for protection during hull cleaning.

19-4.3.1.35 (DV) Fit the anode loosely over the stud to confirm that it fits. If it does not, mark the anode where it rubs and return it to the surface. If necessary, file away the minimum of ceramic to fit the anode over the studs. (See [Figure 19-8](#).) On completion, make sure the washers on the studs still provide adequate overlap on the enlarged hole.

WARNING

Operators of sandblasting equipment must be familiar with and observe the Warnings and Cautions contained in [Appendix B](#) to this chapter.

19-4.3.1.36 (DV) Prepare the exposed hull area to receive the replacement anode by sandblasting the bare metal to a near-white metal finish in accordance with SSPC-SP10.

NOTE

Most underwater epoxies bond most effectively to a slightly uneven (roughened) surface. A sandblasted surface is ideal. The edge of the dielectric shield should be faired by the sandblaster to a 20-30 degree angle to receive the epoxy.

NOTE

The supervisor must ensure that the time between surface preparation and epoxy paint application is kept to a minimum. If a prepared surface is left for a lengthy period without paint, it will begin to rust and the surface will have to be sandblasted again before paint application. Similarly, an oily film can form in a very short time and prevent successful paint application. Wiping the prepared surface with a concentrated detergent ("Joy") immediately before paint application can help the paint to adhere.

19-4.3.1.37 (DV) Sandblast the edge of the existing dielectric shield to create a surface suitable for subsequent fairing in of the approved epoxy (see [Appendix A](#)).

19-4.3.2 Anode Replacement

NOTE

Apply duct tape layers in patterns that both protect and are easy to remove.

19-4.3.2.1 (TOP) Using duct tape, apply a protective layer of strips sufficient to cover the top of the replacement anode. This will keep epoxy from fouling the anode surfaces. Carefully cut out holes in the tape layer corresponding to the anode securing holes. The anode surface must be protected from epoxy fouling but must also provide accessibility to the securing studs. Fit a protective cover of duct tape over the male probe extending from the anode hub.

CAUTION

Epoxies, paints, and solvents are toxic and can cause serious injury to eyes and skin. Wear protective goggles, coveralls, and impervious rubber gloves during mixing and application. Epoxies, paints, and solvents emit toxic fumes. Ensure adequate ventilation for personnel during mixing, application, or cleanup of toxic materials.

19-4.3.2.2 (TOP) Apply a layer of epoxy to the back of the anode, keeping a margin 1 inch wide around the anode hub free of epoxy. Place the neoprene mat onto the anode carefully, guiding the anode hub through the mat hub hole. Ensure the anode hub is not damaged and the mat holes are aligned with anode stud holes. The neoprene mat will not completely cover the anode and there will be an outer margin around the mat where the anode is exposed. Apply another layer of epoxy to this exposed margin to build it to the same level as the edge of the neoprene

mat.

19-4.3.2.3 (DV) Remove the nuts protecting the anode securing studs. Remove the pre-soaked DC plug from the hull penetration, exposing the stuffing tube.

19-4.3.2.4 (TOP, DV) Pass the prepared anode to the divers for transport to the hull.

19-4.3.2.5 (DV) Remove the duct tape covering the male probe extending from the anode hub. Carefully locate the anode over the securing studs so that the anode hub projects into the stuffing tube, and the securing studs project through the anode stud holes.

CAUTION
Uneven or extreme tightening of securing bolts will shatter the ceramic surface of the anode holder.

19-4.3.2.6 (DV) Place a washer and hex nut on each securing stud to hold the anode and, starting from the centermost studs, tighten each nut using only moderate torque. Tighten all nuts evenly, waiting several minutes between successive tightenings to permit the epoxy to squeeze against the prepared hull surface and flow out from the back of the anode. Tighten all nuts to a torque of 10 ft.-lbs.

CAUTION
The careful application and successful bonding of epoxy is crucial to the repair.

19-4.3.2.7 (DV) Press the squeezed epoxy around the anode evenly, fairing in the anode and marrying the epoxy to the clean, roughened existing dielectric shield edge. Cover all metal hull areas. Add additional 20 mil layers of epoxy as necessary to completely fill and fair the gap between the old shield and the replacement anode. Evenly fill in any irregular or trimmed areas of dielectric shield so that the integrity of the shield is completely restored.

19-4.3.2.8 (DV) Apply the approved epoxy to fill the securing nut holes in the tape layer above the anode securing nuts (8 or 16), fairing the epoxy to the upper surface of the anode. When all epoxy has been applied, carefully remove the duct tape from the anode. All epoxy must now cure at a rate dependent upon ambient water temperature (see the graph in [Appendix A](#)).

CHANGE **19-4.3.2.9 (SF)** Vent and remove the internal blanking plug.

19-4.3.2.10 (SF) If necessary, clear the anode gland of any water with an air hose (a whip leading from a scuba bottle would be appropriate). Dry and recoat the gland with silicone grease.

NOTE

When Teflon is compressed it will creep, i.e. slowly distort and flow away from the compressive force. The Teflon packing rings are the primary watertight seal. To ensure that the Teflon rings form an effective watertight seal it is essential that the gland nut compressing the Teflon rings is retightened 24 hours after the initial compression.

CAUTION

Do not tighten the packing nut down onto the top of the anode hub. If the correct number of packing rings have been fitted properly, this should not be possible.

19-4.3.2.11 (SF) Tighten the packing nut with a 1 3/8-inch socket wrench until the packing is compressed to the limit. Retighten at intervals until tight and the Teflon has crept as far as possible. Repeat the operation one hour later and 24 hours later.

19-4.3.2.12 (SF) Assemble two O-rings to the female prong assembly. Lubricate the female prong assembly and O-rings with silicone grease.

19-4.3.2.13 (SF) Install the truarc ring, female prong assembly and packing nut, then tighten down the packing nut.

19-4.3.2.14 (SF) Install gland gasket, connection box, gasket for the connection box cover, and the connection box cover.

19-4.3.2.15 (SF) Install insulating washers, washer, nut, washer, anode cable lug (with cable), lock washer, and nut.

19-4.3.2.16 (SF) For protection against water, hull penetrations may have connection boxes fitted with a fill hole. Fill the connection box with paraffin. Insert the pipe plug in the tapped fill hole.

19-4.3.2.17 (SF) Replace the high-hat cofferdam cover if the connection box is located in a tank or void space.

CAUTION

Epoxy must be fully cured before the ICCP system is tested. Depending on ambient water temperatures, this could take several days.

19-4.3.2.18 (DV) After an adequate cure period, visually inspect the epoxy applications. Confirm that the epoxy has cured and appears properly bonded to the existing dielectric shield.

19-4.3.2.19 (SF) When the epoxy cure has been confirmed, the ICCP system is ready for testing.

19-4.3.2.20 (SF) Energize the ICCP system to assure the proper operation of the replacement anode. Procedures for inspection and adjustment of system operation following shutdown and testing replacement anodes are provided in NSTM 633, Section 6.

19-4.4 REFERENCE CELL REMOVAL AND REPLACEMENT PROCEDURE

WARNING

Underwater electrical equipment must be secured while divers are working over the side. Hull deterioration is most severe while the ICCP system is de-energized and the effects are irreversible. The appropriate zone of the ship's ICCP system must be secured, tagged out, and confirmed secured before divers may work on an ICCP device (anode, dielectric shield, or reference cell). When divers are required to work in close proximity to an active ICCP anode and risk of contact with an anode exists, that part of the system must be secured for the duration of the repair. In other than these situations the ICCP system is to remain active. Divers working within 15 feet of an active system must wear a full dry suit, unisuit, or wet suit with hood and gloves. Clear communications among divers, surface personnel, and inboard Ship's Force personnel are crucial for safe and effective coordination of tasks and the maintenance of watertight integrity at through-hull penetration sites.

19-4.4.1 The activity conducting the reference cell removal and replacement shall:

- a. Ensure all required materials are on hand using [Table 19-2](#) for guidance.
- b. Coordinate material, technical, and funding requirements.
- c. Conduct reference cell replacement training in accordance with Naval Ships' Technical Manual, S9086-VF-STM-010/CH-633, "Cathodic Protection."

- d. Arrange with the ship for control and disposal of hazardous material.
- e. Prepare video and still cameras to document work throughout the procedure. Notify the ship of any special precautions required in the performance of removal/replacement.

19-4.4.2 The Ship's Force shall:

- a. Ensure that the ship is moored with the affected cell toward the pier.
- b. Tag out equipment and systems for conduct of diving operations.
- c. Control and dispose of hazardous material as agreed to with the performing activity.

19-4.4.3 (SF) Defuel and gas free the compartment in which the reference cell hull penetration is located, and other compartments as necessary to access the reference cell (if the cell is located outboard of a tank/void).

19-4.4.4 (SF) Rig lighting and establish ladders and scaffolding as necessary to access the reference cell.

19-4.4.5 (SF) Provide a sentry at the reference cell hull penetration who is able to maintain verbal contact with working personnel, especially if they are in an enclosed compartment.

19-4.4.6 Verify that the appropriate zone of the ICCP system has been de-energized and tagged-out. The rest of the ICCP system should remain energized, ionizing the hull.

19-4.4.7 (SF, TOP, DV) Establish communications between the inboard side of the reference cell hull penetration (Ship's Force sentry), the dive supervisor, and the divers.

NOTE
The dive supervisor must be satisfied that the preparatory steps [19-4.4.3](#) through [19-4.4.7](#) have been completed before proceeding.

19-4.4.8 (SF) Remove the cover plate of the high-hat cofferdam housing the reference cell gland assembly ([Figure 19-12](#)).

19-4.4.9 (SF) Inspect and remove the high-hat cofferdam gasket. Replace the gasket if necessary.

19-4.4.10 (SF) Inspect the inside of the cofferdam/high hat for signs of corrosion or fuel/liquid ingress. If there are signs ascertain the cause of the ingress and, if possible, rectify the defect.

NOTE

If the problem can not be rectified then a decision should be made whether to continue with the replacement while a potential root cause for the defective reference cell exists.

19-4.4.11 (SF) Remove the gland nut. Because of its position inside the high-hat cofferdam it is necessary to use a wrench with an extension piece and a crow's foot with an internal jaw diameter of 1 1/8 inch.

19-4.4.12 (SF) Remove the cable and packing assembly by hand.

19-4.4.13 (SF) Determine if the Teflon bushing is still in place. If it is loose, remove it.

19-4.4.14 (SF) Inspect the walls of the gland body for signs of water entry.

19-4.4.15 (SF) Fit a straight-threaded blanking plug into the gland body.

NOTE

The straight threaded blanking plug must be manufactured locally. It is fitted in place of the gland nut. It should be manufactured with a 1/4 turn vent valve and an O-ring, with a 1-inch 12 UNF-1A thread pattern (see [Figure 19-13](#)).

The old gland nut could be fitted with a 1/2-inch male with plain end vent valve to make this blanking plug.

19-4.4.16 (DV) Remove the fairing epoxy from the six reference cell securing screws using a small hand-held chisel.

19-4.4.17 (DV) Using a flat tip screwdriver, loosen the six screws in a star pattern, giving each screw one turn.

19-4.4.18 (DV) Completely remove all screws and lockwashers. Retain them at the work site.

19-4.4.19 (SF) Verify the inboard watertight integrity of the gland blanking plug by opening then closing the vent plug valve. There should be no flow of water before proceeding.

19-4.4.20 (DV) Using at least two soft wood wedges, slowly lift the reference cell from the sole/backing plate.

19-4.4.21 (DV) Remove the reference cell from the hull and verify the position of the Teflon

bushing (if not removed earlier). Send the reference cell to the surface.

19-4.4.22 (SF) Inspect the internal bore of the gland body for corrosion/roughness. Hand clean with a cloth as necessary.

19-4.4.23 (DV) Fit a mechanical expandable plug or a pre-soaked DC plug into the mouth of the reference cell gland body. (The plug should fit a 1 1/8 inch I.D. opening and be no longer than 1 1/2 inches.)

19-4.4.24 (DV) Replace the screws removed in [step 4.4.18](#). This will protect the internal threads of the bolt holes during hull preparation.

WARNING
Operators of sandblasting equipment must be familiar with and observe the Warnings and Cautions contained in [Appendix B](#) to this chapter.

19-4.4.25 (DV) Using an underwater sandblaster, clean the sole/backing plate area of the hull onto which the reference cell mounts. Prepare it to a near-white metal finish (SSPC-SP-10).

19-4.4.26 (DV) Remove the reference cell securing screws fitted in [step 4.4.24](#). Retain at the work site.

19-4.4.27 (DV) Screw six threaded guide rods into the securing bolt holes to help locate the replacement reference cell. Each rod should be 6 inches long, 1/4-20 UNC-2A all-thread. (See [Figure 19-14](#)).

19-4.4.28 (DV) Remove the mechanical expandable plug or DC plug.

19-4.4.29 (DV) Evacuate any water from the reference cell gland assembly using the diver's pneumo.

19-4.4.30 (DV) Using a straight scribe, unseat the Teflon bushing by pushing it back up into the gland body penetration (as required).

19-4.4.31 (DV) Replace the mechanical expandable plug or DC plug.

WARNING

Epoxies, paints, and solvents are toxic and can cause serious injury to eyes and skin. Wear protective goggles, coveralls, and impervious rubber gloves during mixing and application. Epoxies, paints, and solvents emit toxic fumes. Ensure adequate ventilation for personnel during mixing, application, or cleanup of toxic materials.

19-4.4.32 (TOP) Prepare the epoxy and pass to the divers for application to sole/backing plate.

19-4.4.33 (DV) Coat the prepared backing/sole plate with epoxy.

NOTE

The supervisor must ensure that the time between surface preparation and epoxy paint application is kept to a minimum. If a prepared surface is left for a lengthy period without paint, it will begin to rust and the surface will have to be sandblasted again before paint application. Similarly, an oily film can form in a very short time and prevent successful paint application. Wiping the prepared surface with a concentrated detergent ("Joy") immediately before paint application can help the paint to adhere.

NOTE

Apply duct tape layers in patterns that both protect and are easy to remove.

19-4.4.34 (TOP) Using duct tape, apply a protective layer of strips sufficient to cover the outboard side of the replacement reference cell. This will keep epoxy from fouling the reference cell surface or clogging the sensor holes. Carefully cut out holes in the tape layer corresponding to the six reference cell securing holes. Place the prepared replacement reference cell in a basket and pass to the divers for transport to the hull.

19-4.4.35 (DV) Remove the mechanical expandable plug or DC plug. Heavily apply silicone grease to the O-rings of the reference cell and the internal bore of the gland body.

19-4.4.36 (DV) Locate the reference cell over the six guide rods, and push it into position onto the hull until it mates with the sole/backing plate. If an air lock is experienced in the gland body, release the pressure by venting the blanking plug.

19-4.4.37 (DV) Replace each guide rod with a securing screw and lockwasher, hand tighten each screw just until it touches the reference cell.

19-4.4.38 (DV) Using the star pattern, torque each screw to 10 ft.-lbs.

19-4.4.39 (SF) Slowly remove the gland blanking plug, checking for any signs of water entry past the reference cell O-rings.

19-4.4.40 (SF) If the Teflon bushing was not removed in previous steps, use a right-angled scribe to remove it at this time. If the Teflon bushing was not properly pushed in from the outboard side ([paragraph 19-4.4.30](#)), it could become wedged around the reference cell male probe and be difficult to remove.

19-4.4.41 (SF) Check the electrical voltage continuity of the reference cell by measuring the voltage between the steel hull and the reference cell using a multimeter. If the system is functioning correctly, the hull will be negative and the reference cell will be positive. The DC voltage should measure approximately 0.6 volt DC.

NOTE

If the voltage is zero, it indicates either an open wire or a shorted wire or cell. If the voltage is higher than indicated, the hull is receiving cathodic protection from some other source (zincs or electrical leakage). On a newly painted steel hull the reading may be as low as 0.45 volt DC.

19-4.4.42 (DV) Fill the screw holes with epoxy and fair to the reference cell surface. When all epoxy has been applied remove the duct tape.

19-4.4.43 (SF) Clean and grease the internal surface of the gland body and insert a new Teflon bushing, packing assembly, and cable.

NOTE

When Teflon is compressed it will creep, i.e. slowly distort and flow away from the compressive force. The Teflon packing ring is the primary watertight seal. To ensure that the Teflon rings form an effective watertight seal, it is essential that the gland nut compressing the Teflon is retightened several times.

19-4.4.44 (SF) Insert the gland ring and lockwasher, then screw in the gland nut by hand. Using a torque wrench with an extension piece, a crow's foot and an internal jaw diameter of 1

1/8 inch, tighten the gland nut to 25 ft.-lbs. Retighten 6, 12, and 18 hours later.

19-4.4.45 Energize the ICCP system to ensure the proper operation of the replacement reference cell. Procedures for the inspection and adjustment of system operation following shutdown and for the testing of replacement reference cells are provided in Naval Ships' Technical Manual, Chapter 633, Section 6.

19-4.5 DIELECTRIC SHIELD REPAIRS

WARNING

Underwater electrical equipment must be secured while divers are working over the side. Hull deterioration is most severe while the ICCP system is de-energized and the effects are irreversible. The appropriate zone of the ship's ICCP system must be secured, tagged out, and confirmed secured before divers may work on an ICCP device (anode, dielectric shield, or reference cell). When divers are required to work in close proximity to an active ICCP anode and risk of contact with an anode exists, that part of the system must be secured for the duration of the repair. In other than these situations the ICCP system is to remain active. Divers working within 15 feet of an active system must wear a full dry suit, unisuit, or wet suit with hood and gloves. Clear communications among divers, surface personnel, and inboard Ship's Force personnel are crucial for safe and effective coordination of tasks.

19-4.5.1 The activity conducting the dielectric shield repair shall:

- a. Ensure that all required materials are on hand using [Table 19-3](#) for guidance.
- b. Coordinate material, technical, and funding requirements.
- c. Conduct dielectric shield repair training in accordance with Naval Ships' Technical Manual, S9086-VF-STM-010/CH-633, "Cathodic Protection."
- d. Arrange with the ship for control and disposal of hazardous material.
- e. Prepare video and still cameras to document work throughout the procedure.
- f. Notify the ship of any special precautions required in the performance of the

shield repair.

19-4.5.2 The Ship's Force shall:

- a. Ensure that the ship is moored with the affected dielectric shield toward the pier.
- b. Tag out equipment and systems for conduct of diving operations.
- c. Control and dispose of hazardous materials as agreed to with the performing activity.

19-4.5.3 Verify that the appropriate zone of the ICCP system has been de-energized and tagged out. The rest of the ICCP system should remain energized, ionizing the hull. The energized zone must remain tagged out until the epoxy has cured.

CAUTION
Particular care must be exercised to protect the anode from damage during sandblasting.

19-4.5.4 Prepare the dielectric shield for application of the aquatic epoxy paint by removing all loose and damaged Capastic. Areas of bare metal shall be prepared to as near-white metal finish (SSPC-SP-10) as possible using an OceanClean Sandblaster. Use the sandblaster to fair the edges of sound Capastic to a 20-30 degree angle. For minor repairs and to repair cracks at the anode/Capastic shield interface, a right-angled grinder may be used.

NOTE
The supervisor must ensure that the time between surface preparation and epoxy paint application is kept to a minimum. If a prepared surface is left for a lengthy period without paint, it will begin to rust and the surface will have to be sandblasted again before paint application. Similarly, an oily film can form in a very short time and prevent successful paint application. Wiping the prepared surface with a concentrated detergent (e.g. "Joy") immediately before paint application can help the paint to adhere.

19-4.5.5 Follow the manufacturer's instructions for mixing the epoxy paint system.

NOTE

Two-part epoxies generally begin curing as soon as the components are mixed. The minimum amount of paint required should be mixed at any one time.

19-4.5.6 Apply the epoxy paint by hand, trowel, paint brush, or for large areas, by a paint application machine.

NOTE

Painting underwater requires patience. Divers must avoid the temptation to try to paint too much surface at one time. Too much paint applied at one time often results in the paint peeling away from the prepared surface before it has time to adhere. Best results are obtained from working the paint into the prepared surface, especially in areas of pitting. In these areas it is important to work the paint into the surface to expel as much water and air as possible.

19-4.5.7 Fair the epoxy up to the edge of the anode and flush with the sound epoxy. Refer to [paragraph 19-1.4.6.d](#) for required thickness. Do not paint the surface of the anode except when fairing in the anode securing bolts.

NOTE

Experience with epoxy paints has shown that application in temperatures lower than 50 degrees F is not advisable. In general, the lower the seawater temperature, the longer the cure time.

19-4.5.8 Calculate the required cure time using the graph in [Appendix A](#).

19-4.5.9 Upon completion of the required cure time, visually inspect the epoxy application. Confirm that the epoxy is cured and appears properly bonded to the existing dielectric shield.

19-4.5.10 When the epoxy cure has been confirmed, energize the ICCP system and test in accordance with Naval Ships' Technical Manual, Chapter 633, Section 6.

19-4.6 POST-REPAIR PROCEDURES

19-4.6.1 Upon completion of the repair, a written report should be provided to the ship's Engineer officer for the ship's records. The report shall contain all information pertaining to the repair including the completed work package with all Quality Assurance (QA) documents, documentation of the damage assessment (NAVSEA Form 4730/7), photographs, any problems encountered together with their solution, and any post repair action required (e.g., periodic inspections, rework during next dry docking, etc.). A copy of the report should be retained by the repairing activity. A copy of the report should be forwarded to NAVSEA 00C5 when requested.

19-4.6.2 Whenever possible photographic and videotape records of dielectric shield repairs should be taken to provide a reference for the next underwater hull inspection. Copies of these photographic records along with the hull survey report forms should be forwarded, if requested, to NAVSEA (SEA 00C5).