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TITLE

US NAVY CORROSION PRESENTATION

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US Navy Corrosion Presentation

by

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CURRENT CORROSION PROGRAMS
METALS DEPARTMENT
CARDEROCK DIVISION, NSWC

INTERNAVAL CORROSION CONFERENCE
HALIFAX, NS
23 April 1997

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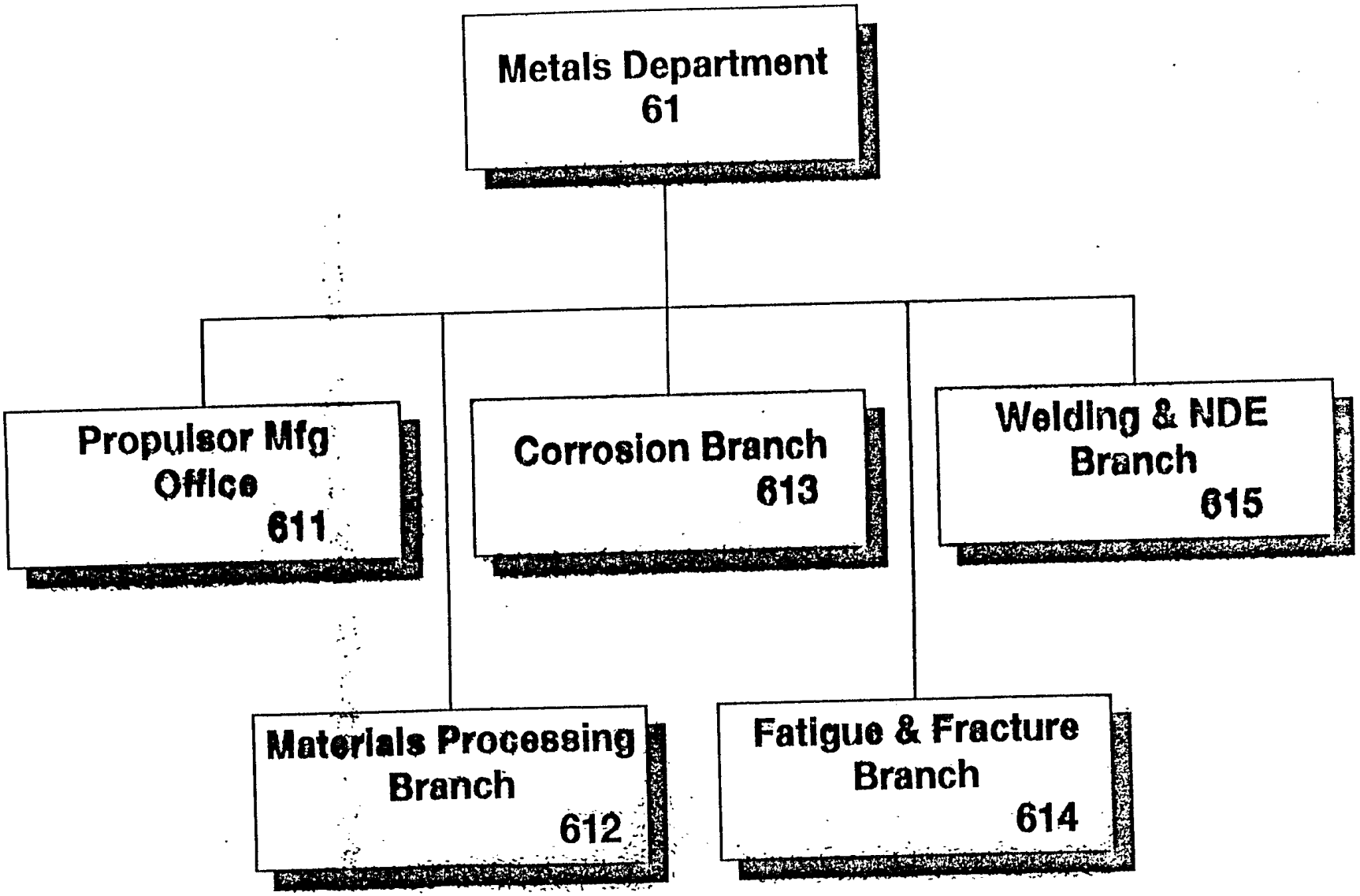
Corrosion Branch - Code 613



Facilities

- **Electrochemical Test Laboratory - DC and AC Equipment**
- **Stress-Corrosion Cracking Test Laboratory**
  - **Slow Strain Rate Test Equipment - Four Units**
- **Seawater and Marine Atmospheric Corrosion Test Sites**
  - **LaQue Center for Corrosion Technology - Wrightsville Beach, N.C.**
  - **CDNSWC Fort Lauderdale, FLA (Code 683)**
  - **NRL Key West, FLA**
- **High Temperature Corrosion Laboratory**
  - **Low Velocity Burner Rigs (LVBR) - Four Units**
  - **High Velocity Burner Rig (HVBR)**
  - **Thermal Gravimetric Analysis - Three Units**
  - **Stress Rupture/CREEP Test Machines - Four**
  - **Furnaces and Molten Salt Pots**
- **Computer Workstations & Networking to Supercomputer**

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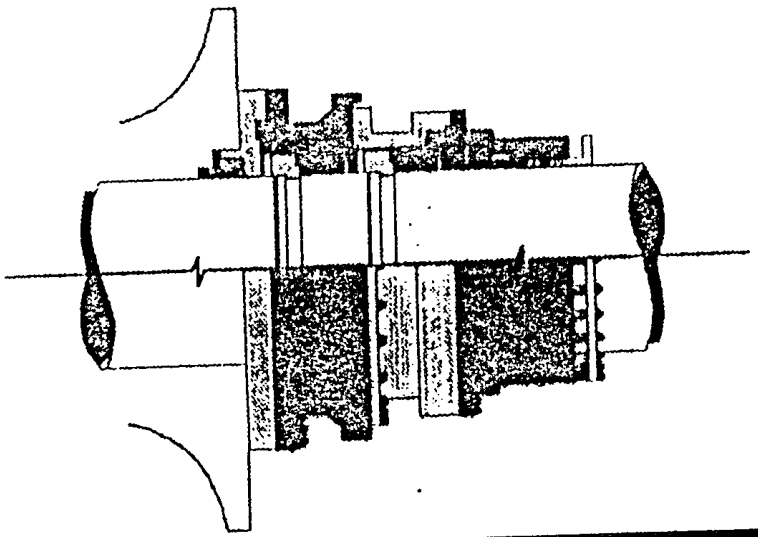
Submarine Shaft Seal Corrosion Control & Repair

POC: E.B. Bieberich (410) 267-2191



Objective

- Determine cause of corrosion of shaft seal materials which increased seal leakage and repair/replacement costs.
- Identify differences in corrosion performance of shaft seal materials and designs for each submarine class.
- Evaluate effectiveness of corrosion control countermeasures and repair methods for shaft seal components.
- Develop standard methods for corrosion control and repair of shaft seal systems.

Technical Approach

- Perform shaft seal corrosion inspections to establish baseline performance.
- Conduct design analysis for OHIO, LOS ANGELES and SEAWOLF Class submarines.
- Conduct comparative evaluations of shaft seal materials and repair methods through corrosion tests and shaft seal physical scale models.
- Characterize corrosion problem areas and identify effective countermeasures and repairs.
- Implement corrosion control countermeasures and repair methods in service and perform fleet evaluations.

Payoff

- Increased reliability of submarine shaft seal systems.
- Extended life of shaft seal system components.
- Standard repair methods and corrosion control countermeasures for shaft seal components.
- Verified performance of repairs and countermeasures through fleet tracking.
- Cost savings through reduced maintenance, repair, and replacement of components.

USMC Corrosion Prevention & Control
Background

USMC operates in corrosive salt air / immersion environment

Equipment purchased without corrosion control design guidance

Corrosion repair and maintenance costs are unacceptable

NSWCCD is conducting both O&M and R&D efforts in support of MARCORSYSCOM CPAC program

Goal is to reduce corrosion and associated life cycle costs for existing vehicles and future acquisitions

NSWC
Naval Surface Warfare Center
CARDEROCK DIVISION

USMC Corrosion Prevention & Control
Approach

Corrosion Surveys

Maintenance Procedures

Coatings

Military & Technical Liaison - CPAC

Equipment Protection for Transport

Corrosion Tests - Marine Atmosphere & Accelerated

Alternate Materials & Design

Field Tests

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Corrosion Control of Double Hull Ships

Objective

- Investigate Approaches To Prevent Corrosion of Double Hull Ships
  - -Advanced Double Hull Combatants
  - -Commercial Double Hull Tankers

Approach

- Three Phase Program Directed by Code 613 (H. Hack)
- Coordinated Efforts of Various CDNSWC Code 60 Organizational Entities With Expertise in Corrosion and Coatings Technologies:
  - -Contract: State-of-Art of Corrosion Control for DH Ships
  - -Codes 622 & 624 (Phila.): Corrosion Susceptibility Analysis
  - -Code 641 (Annapolis): I.D. Optimum Coating(s) for Long Life
  - -Code 68 (White Oak): Investigate Vapor Phase Inhibitors and Dehumidification

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Corrosion Control of Double Hull Ships (cont.)

Results

- **Established Importance of Design Details To Minimize Corrosion and Make the ADH Concept Economically Feasible.**
- **Coatings Systems With 15-20 Years Life and Low VOC Content Are a Realistic Goal Assuming Periodic Maintenance Is Provided.**
- **Use of Vapor Phase Inhibitors or Dehumidification To Reduce Corrosion in Closed Vapor Filled Spaces in the ADH Design Is Feasible.**

Deliverable

- **Co-Authorized Paper Presented at the Advanced (Unidirectional) Double-Hull Technical Sympossium Held at NIST October 25-26, 1994.**

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Corrosion Branch - Code 613

High Temperature Corrosion and Advanced Ceramic Materials

Current and Future Programs

- ICR Gas Turbine Engine (NAVSEA OBR)
  - -Recuperator Section Alloys
    - 14 Cr - 4 Mo Alloy
    - Alloy 625
    - Alloy 230
  - -Hot Section (Turbine Blades) Coatings
- Alternate Fire Fighting Agents - Corrosion Effects
- Super Conducting Current Collectors
- Shipboard Mobility Fuels Program (Code 859)
  - -Red Dye (Identification)
  - -Vanadium
  - -Sulfur
- Textron-Lycoming: Metallic and Ceramic Coatings
- Westinghouse (Orlando): Thermal Barrier Coatings

EIS

- Electrochemical Impedance Spectroscopy
- A-C Test Technique
- Small Alternating Signal (~ 10 mV)
- Wide Signal Frequencies, 10e5 - 10e-3
- Non-Destructive Test
- Research and Practical Tool

QUANTITATIVE NON-DESTRUCTIVE COATING EVALUATION
BASIS OF NAVY NEED

CURRENT PROCEDURE FOR COATING ASSESSMENT AND REPAINT DECISIONS

- NON-QUANTITATIVE & HIGHLY SUBJECTIVE

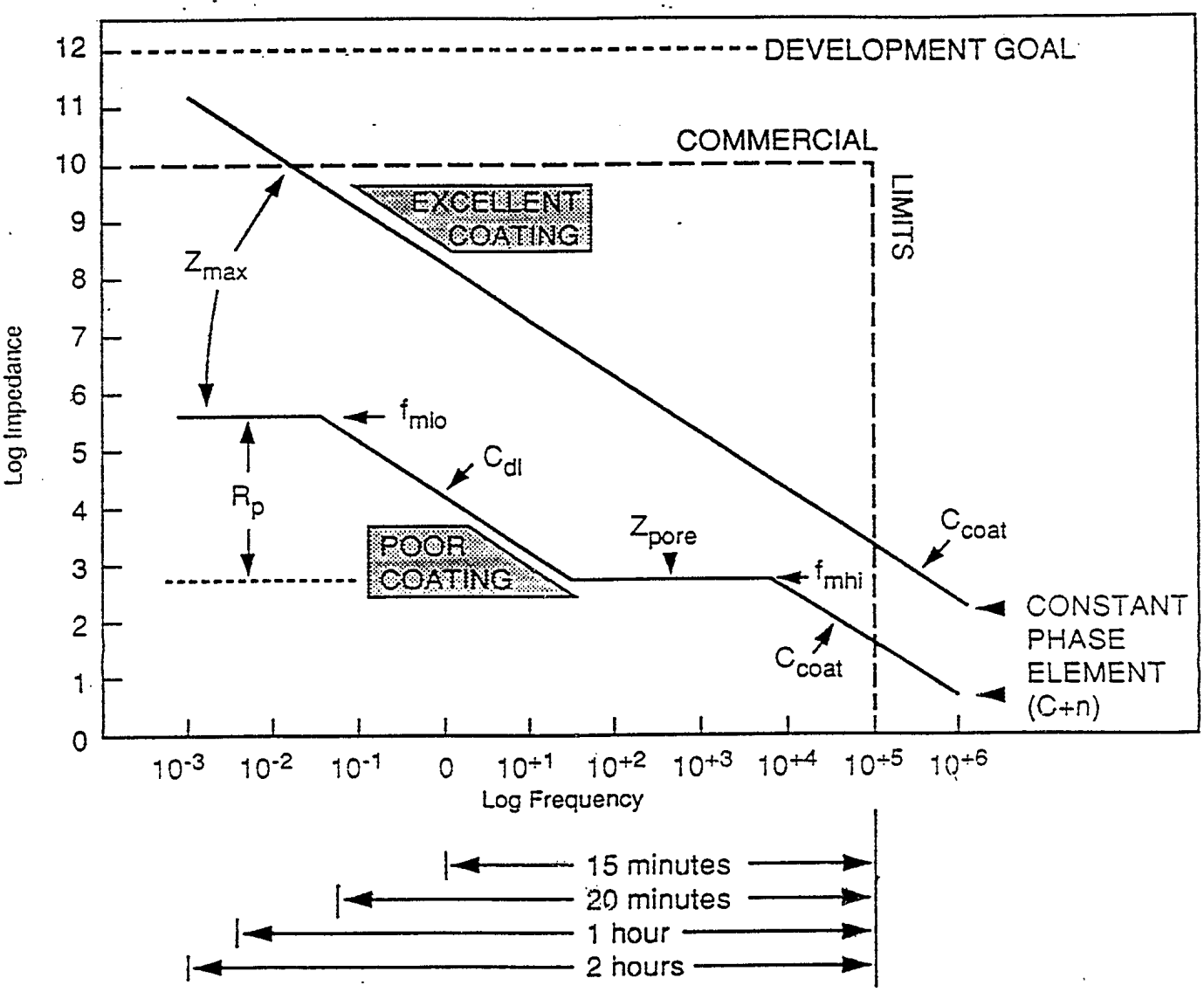
  COATING APPEARANCE COMPARED TO VISUAL STANDARDS SHOWING DEGREE AND DISTRIBUTION OF PAINT DAMAGE

- BLAST AND REPAINT OR TOUCHUP DECISIONS BASED ON THE THE JUDGEMENT OF THE INSPECTOR AND HIS INTEREPRETATION OF THE EXTENT OF COATING DAMAGE

- DRY FILM THICKNESS IS ESSENTIALLY THE ONLY QUANTITAIVE DATA PRESENTLY USED IN COATING EVALUATION

- DRY FILM THICKNESS DOES NOT PRVOIDE INFORMATION ABOUT THE PRESENCE/DISTRIBUTION OF PORES AND HOLIDAYS OR THE CONDITION OF THE COATING/METAL INTERFACE

EIS Coating Assessment Parameters



CURRENT CORROSION PROGRAMS
CARDEROCK DIVISION, NSWC

OTHER PROGRAMS

- Aluminum Alloy Sacrificial Anodes
- Cleaning Agents for Pre-Painting Surface Preparation
- Galvanic Interaction of Piping Materials
- High Strength Fasteners
- Materials Selection for Oily Waste Treatment Systems

CODE 613 TASK WRITE-UPS

Non-Destructive Quantitative Coating Assessment System

NSWCCD (Code 6130) has been developing the methodology and improved field portable equipment for quantitative characterization of the use status of painted metals/conductive substrates. A field-portable electrochemical impedance spectroscopy (EIS) system with higher impedance measuring capability has been successfully demonstrated and improvements to the sampling detector are ongoing. The development of a hand-held meter which rapidly records a high frequency impedance, as related to the general coating status, has been initiated. The hand-held unit would allow a mapping of a hull coating or an internal tank coating system within a conventional work day and target the area(s) for more detailed evaluation via EIS. The methodology would establish a quantitative basis for the necessity of repainting.

Aluminum Alloy Sacrificial Anode

NSWCCD (Code 6130) has led the technical effort aimed at implementing the use of aluminum alloy sacrificial anodes for corrosion protection, which is required when hull or tank paint coating systems fail or become damaged; as a weight saving and mission extending measure. While aluminum anodes generally behave reliably, there is some variability in performance which is related to metallurgical factors and foundry practices. A new study is being initiated to establish the casting requirements for a more favorable and larger microstructure which has been shown to allow excellent, uniform anode performance. The joint test effort is being conducted with the Johns Hopkins University, Materials Science and Engineering personnel. The results and casting recommendations will be made available to all three commercial fabricators of the particular aluminum alloy castings.

Cleaning Agents for Pre-Painting Surface Preparation

NSWCCD (Code 6130) is developing an electrochemical and surface chemistry test protocol for determining the effectiveness of commercially available and developmental repainting cleaning agents. Surface (substrate) contamination has been reported to be the leading cause of coating failures in seawater exposure environments. During the last five years, several vendors (some with very limited laboratory capabilities) have marketed products which are claimed to remove contamination and in some cases are claimed to improve paint adherence. The test protocol is being developed and documented to allow a reproducible assessment of the various products and establish, when required, kinetic and mechanistic information. An environmentally benign product for repainting surface cleaning that increased the performance life of Navy coating systems would result in increased system availability as well as decrease life cycle costs.

ICCP/SHT Adhesion Testing

This task is aimed at assessing the effects of impressed current cathodic protection (ICCP) as compared to the effects of seawater exposure under freely corroding (w/o ICCP) on the reliability/adherence, projected life and maintenance requirements of new hull treatment systems intended for use on NSNN. Cathodic protection parameters which could affect the adhesion of special hull treatment (SHT) materials for the NAS are being assessed. These tests are one of several types which are being used to qualify the materials in general for this application. Test results will be used to recommend any necessary alterations to the SHT or cathodic protection systems.

Corrosion Detection and Identification of Material—Upgrades for Shipboard Seawater Valves

The Navy is replacing certain copper-nickel seawater piping systems with titanium on LPD-17 class ships to reduce life cycle costs. Substitution of titanium for copper-nickel piping, while leaving most of the bronze valves in place, could result in premature deterioration of these valves without full system electrical isolation. Even in current copper-nickel piping systems, corrosion induced deterioration of valves is likely to result in their replacement roughly three times in the 40-year life of a surface ship. In order to avoid unnecessary valve replacement and to extend the life of these valves, a condition-based maintenance system needs to be applied and an alternate, more corrosion-resistant material needs to be identified. The objective of this program is to (1) develop an in-situ, non-destructive method for measuring valve deterioration and (2) identify a seawater valve replacement material (with associated trim materials and design considerations) for a 40-year maintenance free service life. The expected payoff is a life cycle cost savings of $1.5 billion (at least $30-40M/yr) for the Firemain and Auxiliary Seawater Cooling systems in a 200 ship Navy, with equivalent additional savings for other systems and additional ships.

Alloy 625 Life Cycle Program

NSWCCD (Code 613) is undertaking a program to develop crevice corrosion data in representative submarine piping system configurations which would stay ahead of the lead ship in the class and provide the technical basis for establishment of inspection and maintenance periodicity for these systems. To accomplish this, an "all metal piping system" loop is operating under prototypical seawater pressure, velocity and treatment levels. The loop contains plain alloy 625 flanged spools and alloy 625 spools overlaid with alloy C-276 (countermeasure), with all flanges greased prior to assembly. Crevice corrosion inspection intervals on this loop are based on anticipated ship schedules. Also under this program, a crevice corrosion remote detection device is being developed and evaluated in an effort to provide a non-destructive

method of locating crevice corrosion in the complex system geometries where this type of attack is likely to occur. The current device being evaluated is a flange o-ring incorporating an electrochemical sensor. This o-ring also has the potential to provide the component with impressed current protection from crevice corrosion.

High Strength Fasteners

Alloy K-500 is the currently used high strength alloy for Navy fastener applications in immersion service. Alloy K-500 has performed well as a fastener material in seawater but is susceptible to hydrogen cracking in areas of intense cathodic polarization and is galvanically incompatible with titanium and Alloy 625 components. Due to these inadequacies, it is necessary to identify alternate fastener materials that can suitably replace Alloy K-500. Currently, a joint program is being conducted by NSWCCD Codes 613 and 614 to develop a high strength fastener handbook for 15 alloys, containing data and guidelines on corrosion behavior, mechanical properties, fatigue behavior, and other relevant material properties. The technical information in the handbook will include data generated in this program as well as data reported in the literature by government and industry sources. The fastener handbook will be distributed to Navy designers and engineers to assist in joint design for naval systems. Implementation of proper joint design and utilization of appropriate fastener materials will improve fastener reliability and reduce life-cycle maintenance and cost.

Corrosion Control Methods for Advanced Double Hull Ships

Advanced Double Hull ships present some unique problems with respect to controlling and monitoring corrosion due to limited access to and inability to inspect the cells that comprise the ADH design. NSWCCD Codes 613 (Corrosion Branch) and 683 (Electrochemistry Branch) are conducting a joint investigation of corrosion control methods that offer an alternative or enhancement to the use of coatings for use in Naval and commercial cargo advanced double hull (ADH) ship designs. Alternative corrosion control methods to coatings are being tested because of the high cost of coating application for advanced double hulls, and the difficulty of monitoring the condition of coatings in these areas of limited access. Tests are being conducted at an NSWCCD corrosion test site in Ft. Lauderdale, Florida. Results will be used to select and implement long-term corrosion protection methods for ADH compartments and predict their long term corrosion rates. The corrosion inhibition methods being tested are intended to mitigate corrosion and reduce corrosion control costs (relative to coating) and inspection periodicity; all with reduced environmental impact. Successful implementation of these corrosion control methods will improve ship survivability and reduce maintenance costs.

GALVANIC CORROSION PREVENTION IN PIPING SYSTEMS

(NSWCCD Code 6130) Galvanic corrosion of ships piping due to the use of dissimilar metals is becoming of greater concern because of the increased variety of materials used for piping construction of new ships such as the 688 and 21 class submarines. Current design requires periodic inspections and replacement of waster pieces which is expensive and necessitates shutdown of critical ship systems for maintenance. These inspection pieces are in subsafe systems on the submarines which create a safety issue. Galvanic isolation and electrically isolated separator pieces are not viable control methods due to the complexity or available of system space. Alternative galvanic control methods that would eliminate the need for inspection, improve safety, and control corrosion in piping systems are being investigated. This task will prove the concept and effectiveness of newer galvanic corrosion control methods (barrier coatings, cathodic protection, and bi-electrode) by characterizing their performance of mitigating galvanic corrosion by means of piping mockup tests. A series of piping mockups have been designed to simulate the most probable geometry and existing environmental conditions in naval piping systems. Observation and measurement of any corrosion of the galvanic couples will determine the effectivenes of these control methods. The use of effective galvanic corrosion control methods will furnish ship designers with more piping material options for retrofitting existing systems in the Fleet when necessary and provide greater flexibility for new future submarine and surface ship designs.

MATERIALS SELECTION FOR OILY WASTE TREATMENT SYSTEM

(NSWCCD 6130) This task will evaluate corrosion resistance, erosion resistance, weight, cost, and maintainability for the piping and pump materials presently conceived for a treatment system designed by Code 6330 for the Fleet to process oily waste (200-2000 ppm oil content in seawater) along with a number of heavy metals) to reduce the effluent oil concentration to less than 5 ppm oil (the projected future EPA limit) and some loss of the heavy metals. The waste processing unit operates only when required - on the ship where the system will first be installed, the waste processor will operate about 5 hours every five days; at port the processor would not operate - i.e. the system could lie idle for extended periods of time. The oily waste surge tank is exposed to the atmosphere and may include sulfides. The duty cycle of the system may initiate microbiological corrosion; polluted brackish and seawater may introduce other corrodents to the system. The lack of data on low oil/water media corrosion in the open literature will necessitate testing of different materials in the waste treatment processor at NSWCCD and monitor of materials performance on a present operating shipboard system.