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TITLE

CORROSION SENSORS FOR FIELD APPLICATIONS

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Corrosion Sensors for Field Applications

by

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ABSTRACT

Corrosion damage is recognized as a serious problem in naval operating environments, leading to significant cost penalties, reduced safety and unavailability of equipment. In order to manage corrosion control programs more effectively, quantitative information on the nature of corrosive attack is needed. Such information is a fundamental requirement for condition and predictive/prognostic based corrosion maintenance strategies.

Numerous industrial corrosion measurement techniques are available, each with specific advantages and limitations. In order to obtain maximum information on complex corrosion problems, a multi-technique approach is advocated. The multi-technique corrosion measurement approach can often be applied to single corrosion sensor units, constructed of multiple sensing elements. Many of the commonly applied techniques provide semi-quantitative corrosion information only, a factor that is often overlooked.

Corrosion sensors are a vital element of corrosion surveillance systems, utilized to generate information for effective decision making in corrosion control programs. These sensors have emerged as highly specialized devices for technically challenging field applications. The highly sensitive variety can provide early warning of imminent corrosion damage, long before it is observable by visual means. Sensors for corrosion surveillance under aqueous as well as atmospheric corrosion conditions are described. Recent corrosion sensor developments in the domain of "smart structures" is also discussed.

Corrosion Sensors for Field Applications

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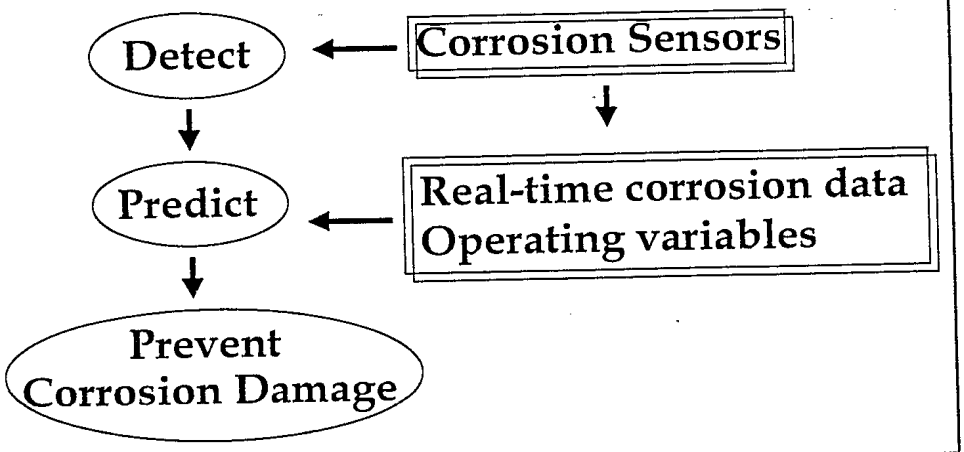
Overview

- Role of Corrosion Sensors
- Three Main Application Areas
  - Smart Structures
  - Inspection and Maintenance Scheduling
  - Testing under Operating Conditions
- Examples of emerging technology
- Summary

Role of Corrosion Sensors

- Is corrosion control effective if corrosion damage cannot be predicted ?
- Can corrosion damage be predicted if it cannot be detected ?

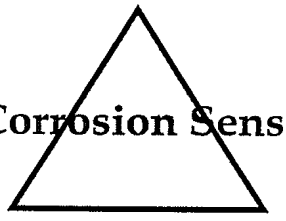
Corrosion Surveillance



Corrosion Sensor Types - Field Use

- Passive Sensors (Coupons)
- Electrical Resistance
- Electrochemical
- Fiber Optics
- Chemical
- Surface Activation (Radiometry)
- Electrical Field Mapping
- Piezo-electric Crystals

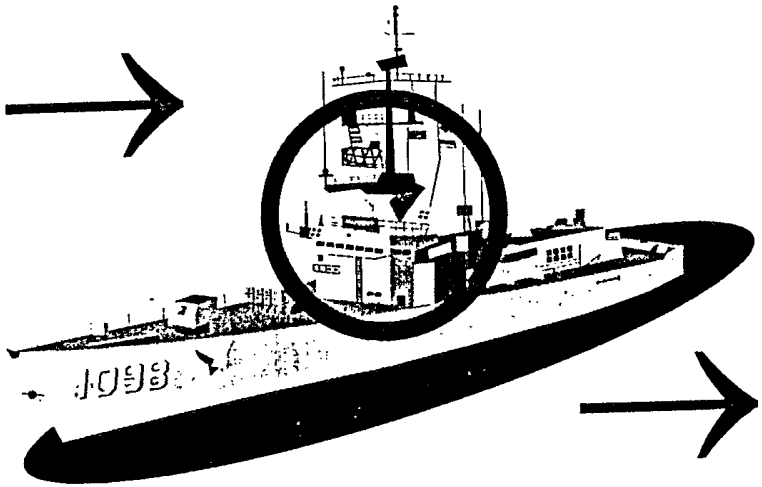
Three Application Areas



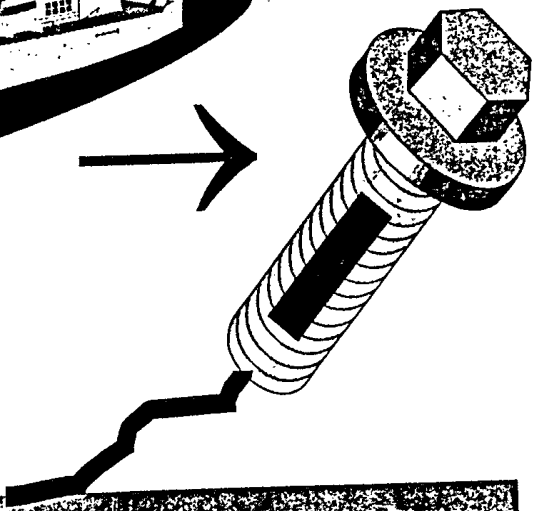
Macro → Micro

Environment

Coupon Sensors



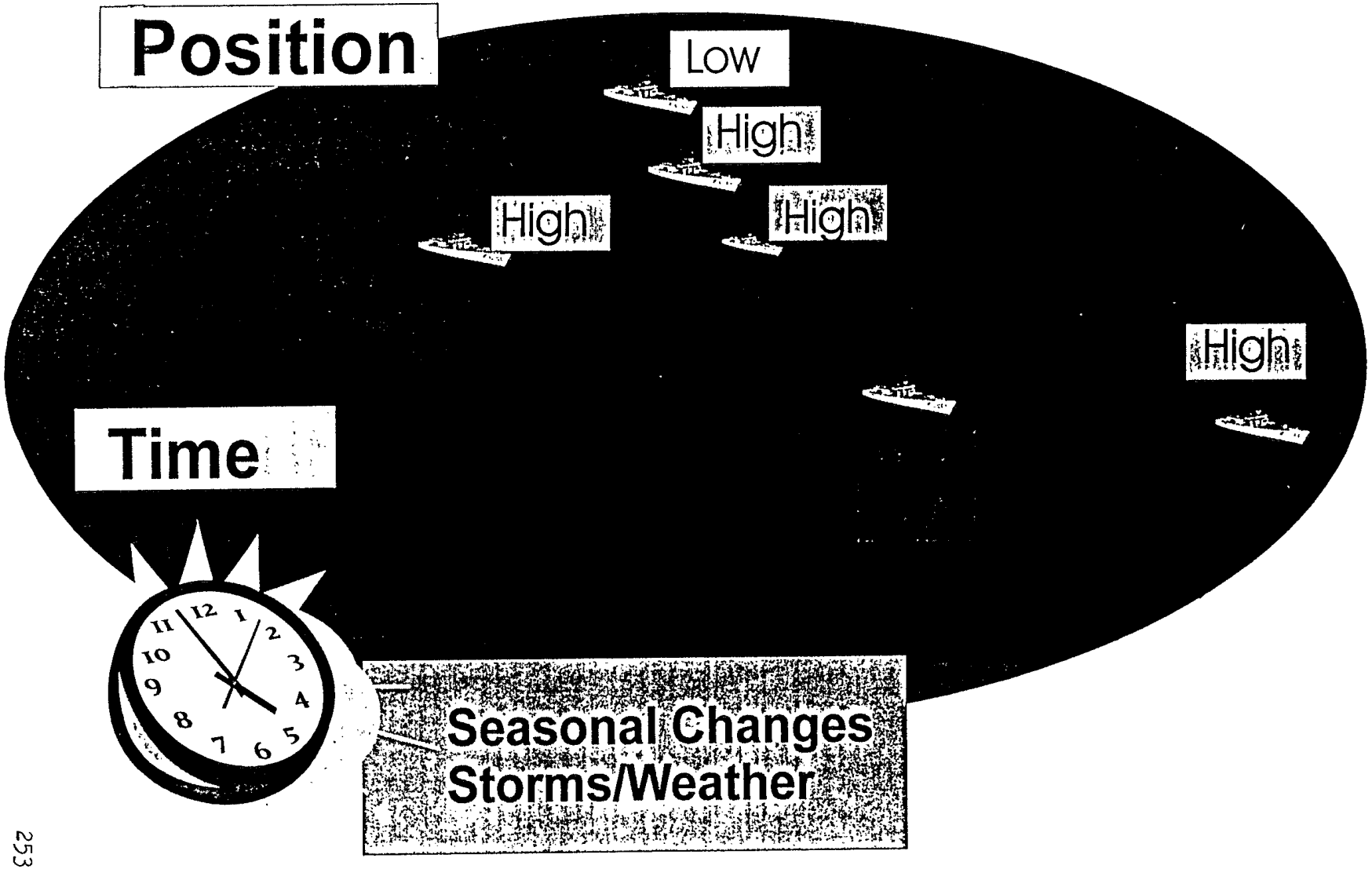
Electrochemical Sensors



Micro Ion Selective Electrodes

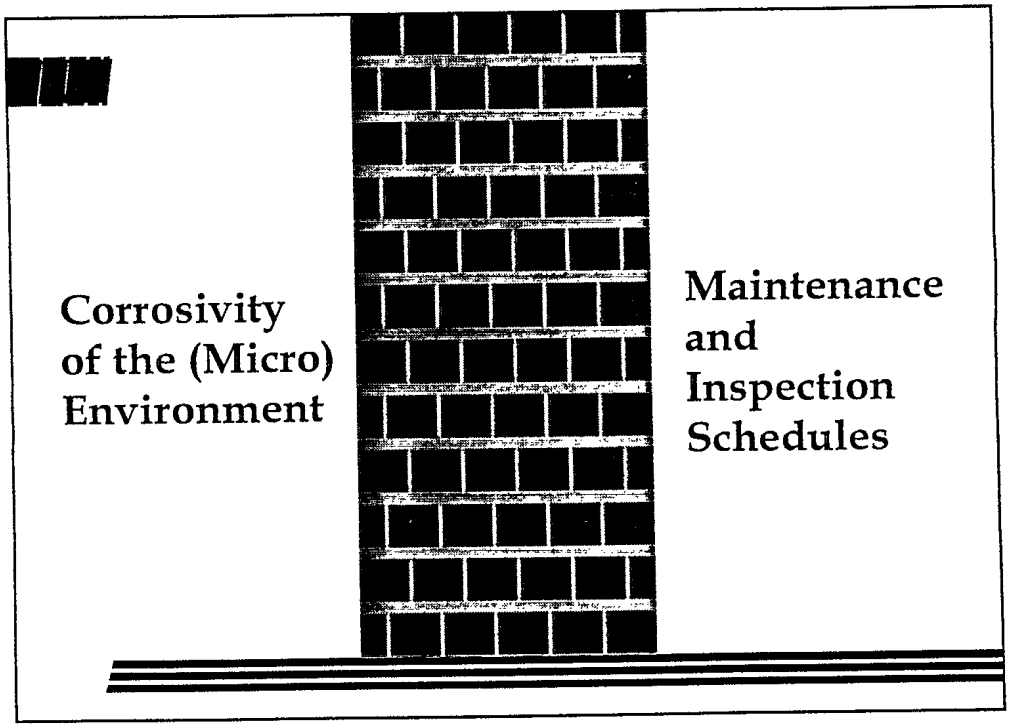
Shipboard Corrosivity

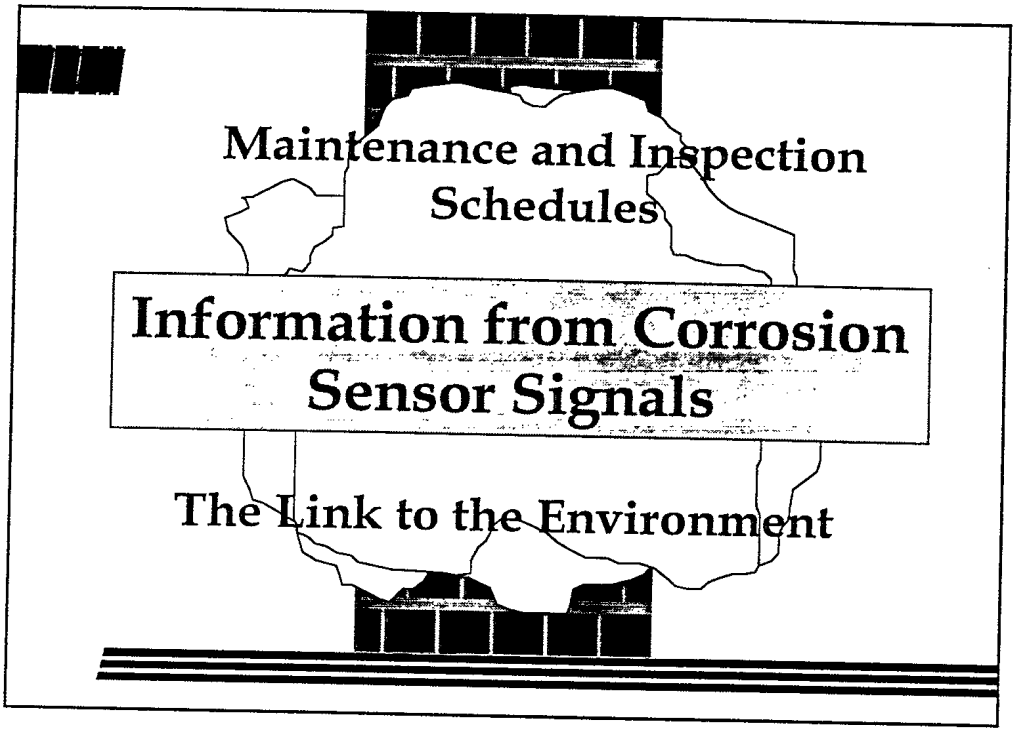
(V.S. Agarwala, ASTM STP 965, 1988)
(E.Tankins et al., JOM, Sept.1995)



Corrosivity of Operating Environment

- Micro-environment most important
- Changes with time, position
- Link to inspection and maintenance scheduling
- Cleaning, inhibitor application, paint repair, repainting





Smart Structures

- Sensors reveal **when** and **where** inspection and maintenance is required
- Condition based vs time based
- Cost driven
  (50-80% maintenance cost savings)*
  (>30% reduction in spares inventory)*

* Survey of 500 plants, Modern Power Systems, July 1994.

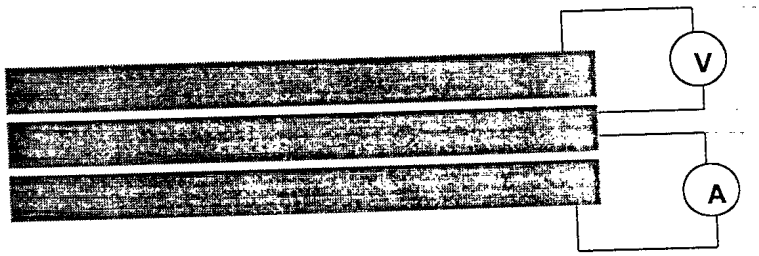
Smart Structure Corrosion Sensors - Paint Coating Degradation

- **Recent Electrochemical Initiatives**
  Elimination of sensor leads
  (Zollars et al. 1997, Kelly et al. 1997)
  Flexible thin film devices
  (Agarwala, 1996)
- **Chemical Color Changes**
  (Agarwala, 1992)
- **Fluorescence**
  (Johnson and Agarwala 1994; 1997 Miller et al. 1995)

Electrochemical Sensors

Principle

- Current and/or potential measurements on closely spaced metallic sensor elements



Electrochemical Sensors

Advantages

- Highly sensitive, early warning

Limitations

- Small area of measurement only
- Sensing elements separated from actual structure
- Non-cumulative data
- Electromagnetic interference

Fluorescent Compounds / Dyes in Coatings

Principles

- Non-fluorescent state to fluorescent state upon oxidation
- Non-fluorescent state to fluorescent state upon complexing with metal ions
- Change in fluorescence from water uptake
- Coloration upon complexing with metal ions

Techniques are still at experimental stage

Fluorescent Compounds / Dyes in Coatings

Advantages

- Large surface areas monitored
- Integral part of coating system, structure

Limitations

- Development and validation is required

Materials Performance Testing, Process Control

Condenser Tubing

(M.A. Winters et al., ASTM STP 1277, 1996)

- Major technical challenge
- Multiple forms of corrosion
- Corrosion and scaling under heat transfer
- Erosion effects
- Representative sensor !

Benefits

- Selection of most cost-effective material
- Reduced maintenance
- Extended service life
- Operating in "safe" windows
- Early warning of problems e.g. "overpickling" in acid descaling