

# Corrosion in Marine Environments & Cooling Systems

September 2014  
NARSA Conference  
Houma, LA, USA

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**“CORROSION IS THE  
DETERIORATION OF A SUBSTANCE  
(USUALLY A METAL) OR ITS  
PROPERTIES BECAUSE OF A  
REACTION WITH ITS  
ENVIRONMENT.”**



**“CORROSION CAN BE EXTERNAL  
(ON THE OUTSIDE OF A STRUCTURE)  
OR INTERNAL (ON THE INSIDE OF A  
STRUCTURE).**



## Forms of Corrosion

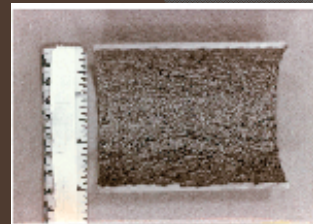
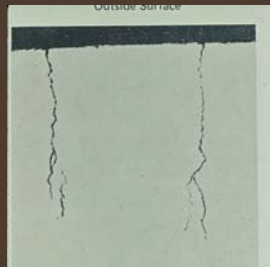
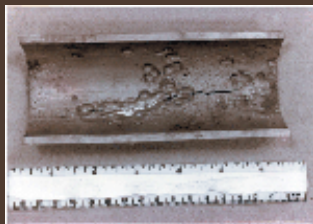
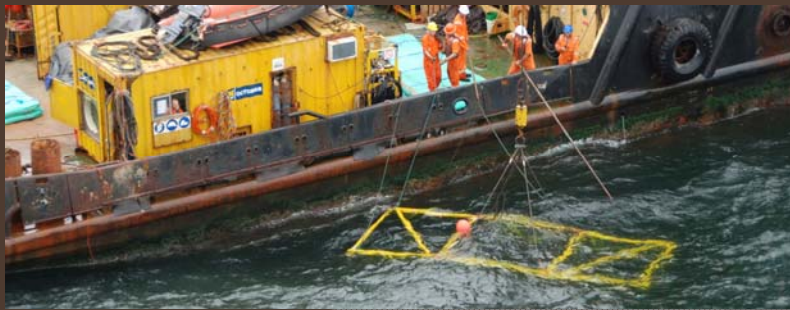


Figure 3 - 1  
extensive su  
Approximately



## Forms of Corrosion – Dive Workboat



## Offshore Structures



## Forms of Corrosion - Platform Helideck



## Offshore Corrosion



## Forms of Corrosion



## Offshore External Corrosion



## Ship Heat-Ex Corrosion



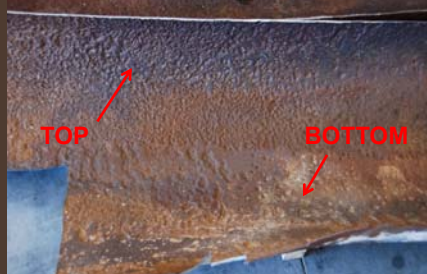
## MIC Corrosion



## Internal MIC Corrosion



## Pipeline Failures !



## Escondida Copper Mine, Chile

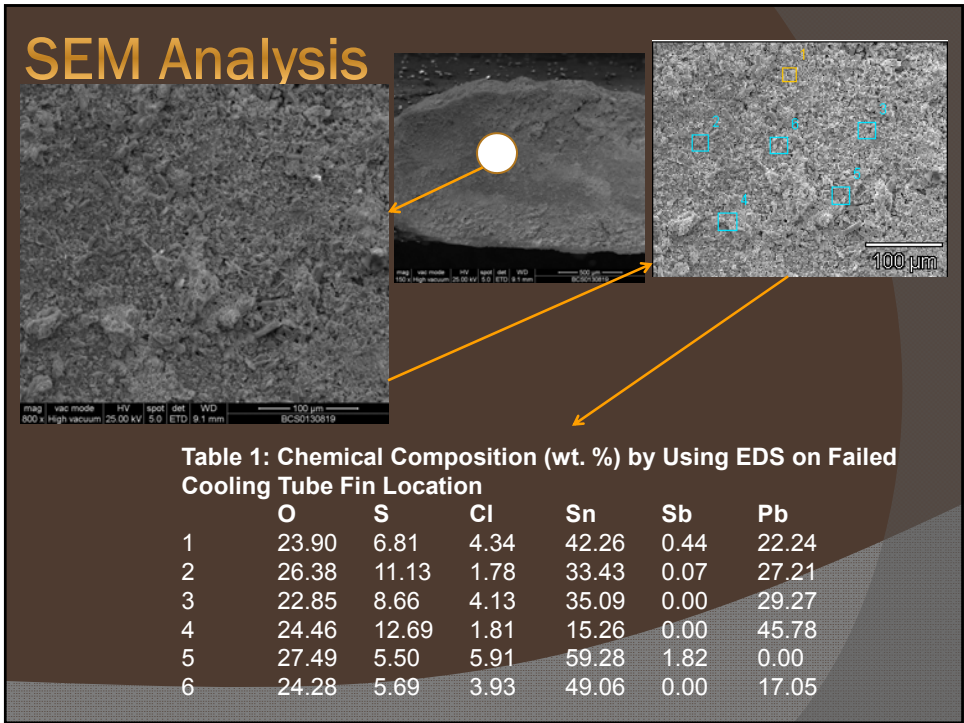


## Vehicle Cooling System Failures



Severely corrosive environment attacked solder bond between fins and tubes in heat exchanger.





## Cooling Tube Failure Testing



## Cooling Tube Failure Testing

Heat Exchanger Flow Test Summary

Type	Anodes	Seawater			Freshwater			50 - 50 Mixture		
		Low	High	CP	Low	High	CP	Low	High	CP
Brand X	No anodes	195	214	NO	300	300	NO	1487	1746	YES
	3 anodes	1034	2154	YES	1220	1350	YES	1706	1713	YES
Brand Y	No anodes	57	223	NO	212	217	NO	812	1282	YES
	2 Anodes	210	379	NO	177	381	NO	85	717	NO
	4 Anodes	805	910	YES	1348	4028	YES	2576	3539	YES

### Cooling Tube Failure Zinc Anodes



New and depleted zinc anodes

### Cooler Anode Failure (60 Hrs.)



Anode isolated

Anode not isolated

## 7 Methods of Corrosion Control

- Material Selection
- Design of the Structure
- Coatings
- Cathodic Protection
- Alteration of the Environment
- Inhibition
- Repair and/or Replace

## MATERIAL SELECTION

**CRA's (Corrosion Resistant Alloys can be used on new structures - BUT - it is expensive, often to the point of not using it.**

## MATERIAL SELECTION



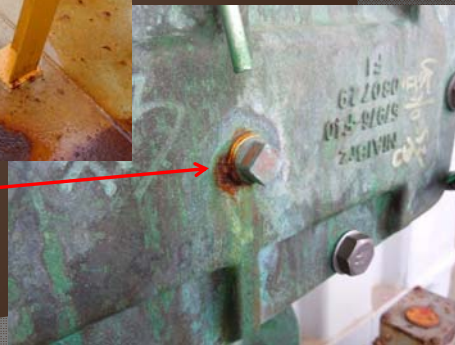
## MATERIAL SELECTION



90 – 10 CuNi Piping  
Ni Al Br Housing

Pipe plugs unknown material

Pipe plug corroded to the point of failure and blew out creating unsafe condition



## MATERIAL SELECTION



90 - 10 Cu Ni

## DESIGN OF THE STRUCTURE

**Proper design can lessen the probability of corrosion:**

Avoidance of crevices and cracks.

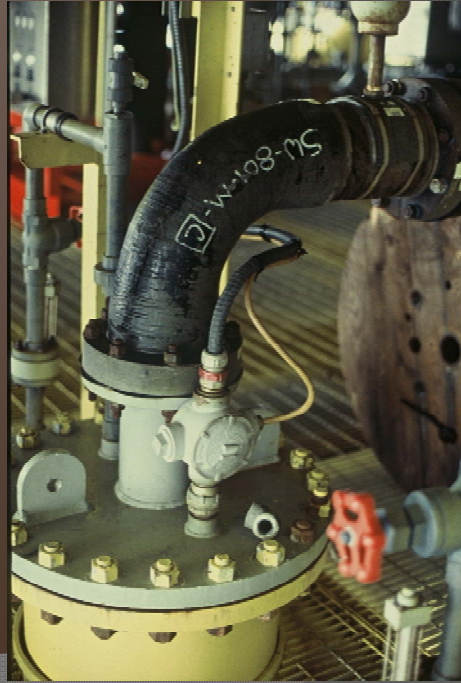
Avoidance of no-flow areas & proper drainage.

Even flow over the surfaces, internal and external.

Proper sizing of pipes, cooling loops, pumps, etc.

Isolation of different materials.

## DESIGN OF THE STRUCTURE



## COATINGS

Coatings are designed to separate the structure from the environment. Inside and outside ... but in coolers it affects the heat exchange properties.

## COATINGS – DRY DOCK FOR RE RE-COATING



## COATINGS





## CATHODIC PROTECTION

**Cathodic Protection (CP) protects the structure by using either Galvanic (Sacrificial) or Impressed Current (ICCP) systems.**

Galvanic CP employs anodes so that the current flow off of the structure goes through the anodes thus they "sacrifice" themselves.

ICCP employs current flowing into the electrolyte through anodes balancing the potential of the electrolyte and the structure so that no current flows off of the structure.

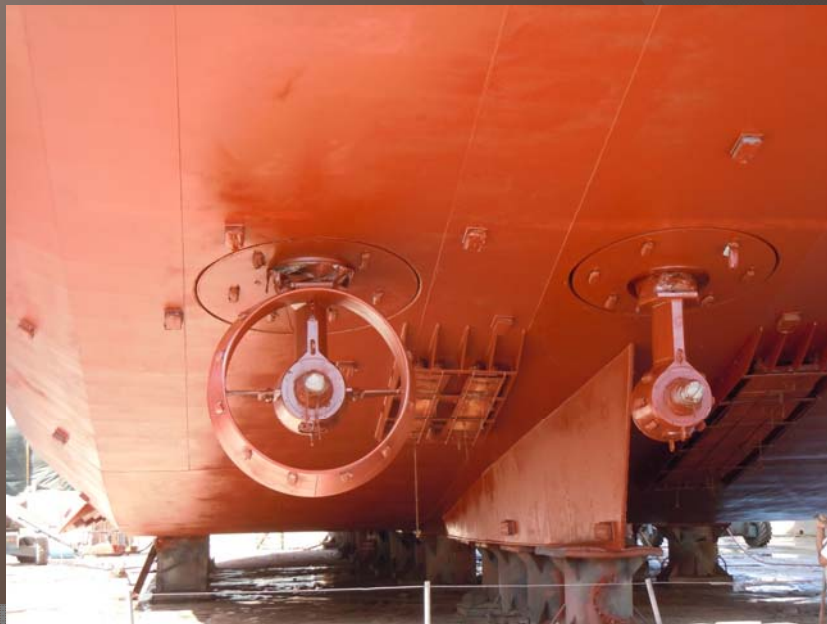
## GALVANIC CATHODIC PROTECTION



## CATHODIC PROTECTION



## CATHODIC PROTECTION



## CATHODIC PROTECTION & MARINE FOULING



## MARINE FOULING



Marine Fouling can affect CP



## MARINE FOULING

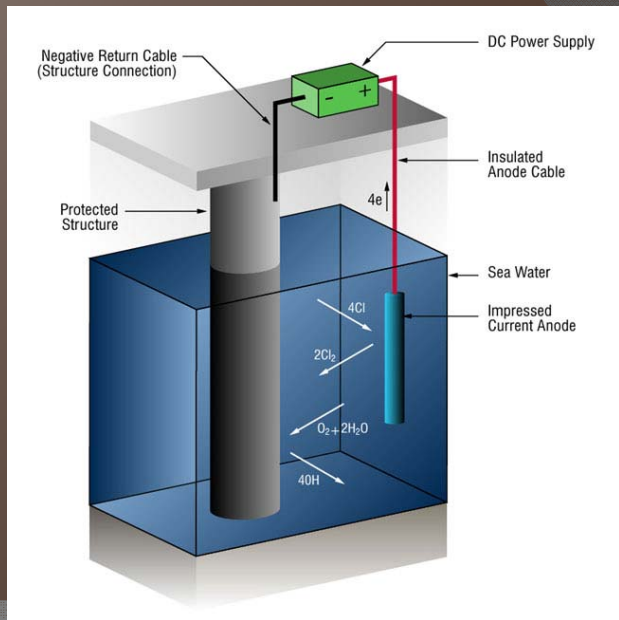
Marine Fouling can affect CP & Heat Exchange Properties!



## CATHODIC PROTECTION



## ICCP CATHODIC PROTECTION



## ALTERATION OF THE ENVIRONMENT - EXTERNAL

Unfortunately the environment is what it is and can not usually be changed externally.

A drill ship built in Pusan sailed to Singapore, Durban and ended up in GOM. 4 different environments.

Deep water GOM vessels start in polluted seawater near the dock and sail into different waters.

Seasonal and location changes.

## ALTERATION OF THE ENVIRONMENT - INTERNAL

The internal environment can often be changed to make it less corrosive and free of marine life, oxygen and chlorides (salt). Closed systems are easier to control than open systems.

Filters and anti-fouling system can be employed.

Sea water can be processed into potable water.

Additives (inhibitors) can be added to create a film between the water and the metal.

Proper drainage.

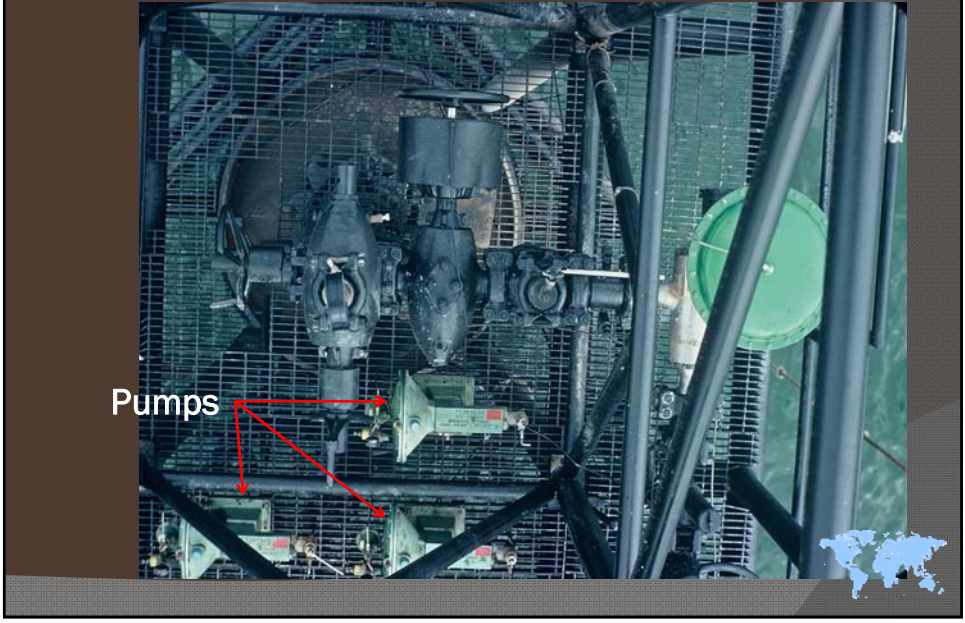
Rinsing salt water with fresh water can greatly lower the corrosion rate.

## INHIBITION

Chemical Inhibition is the use of chemicals to alter the environment and/or create a film that separates the water from the metal thus removing contact between the water and the metal.

Oxygen scavengers  
Biocides  
Corrosion inhibitors  
H<sub>2</sub>S scavengers  
Etc.

# Offshore Chemical Injection



Pumps

## CHEMICAL INHIBITION

Chemical inhibition can be used for a closed internal cooling water but not for external or an open cooling system.

1. Anti fouling system
2. Corrosion inhibitors
3. Biocides
4. Oxygen scavengers
5. Rinse and film

SAFETY DATA SHEET							
PRODUCT							
NALCO® NALCOOL 2000							
EMERGENCY TELEPHONE NUMBER: 800-455-6222 (24 hours) 1-800-455-6222							
<b>1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION</b>							
PRODUCT NAME:	NALCO® NALCOOL 2000						
APPLICATION:	PLANT WATER TREATMENT						
COMPONENT IDENTIFICATION:	Nalco Company 1601 W. Clark Road Naperville, Illinois 60563-1190						
EMERGENCY TELEPHONE NUMBERS:	(800) 455-6222 (24 hours) (630) 770-7700						
HAZ. ID:	2/3	FLAMMABILITY:	0/0	INSTABILITY:	0/0	OTHER:	
0 = Not Hazardous	1 = Slight	2 = Moderate	3 = High	4 = Extreme	+ = Chronic Health Hazard		
<b>2. COMPOSITION/INFORMATION ON INGREDIENTS</b>							
Our local jurisdiction has identified the following chemical substances(1) as hazardous. Consult Section 15 for the names of the hazardous:							
(Hazardous Substances)	CAS# NO.	% by weight					
Sodium Dichromate	15261-85-4	1.0 - 0.0					
Sodium Chromate	1333-83-8	1.0 - 0.0					
Sodium Nitrate	7632-02-0	1.0 - 0.0					
Sodium Nitrite	7632-02-0	1.0 - 0.0					
Sodium Hexafluoroantimonate	2800-45-4	0.0 - 0.1					
<b>3. HAZARD IDENTIFICATION</b>							
<b>EMERGENCY OVERVIEW</b>							
<b>HAZARDS:</b> Contains sodium nitrite. May be harmful or toxic if inhaled. Substances in the product can lead to the formation of hexavalent chromium. Hexavalent chromium can be highly irritating to mucous membranes. May cause skin and eye irritation. May cause sensitization by skin contact. Do not take internally. Keep container tightly closed. In case of spill/leak with water, avoid breathing vapors and wear protective clothing. After contact with skin, wash immediately with plenty of water. If available, flush affected areas immediately and show this container to label. Product produced from recycling. Never inhale particles during filling, grinding and reprocessing. May irritate water of natural (CN) under the conditions. May cause irritant of nitrogen (NOC) under the conditions. If product is added to dry air, sodium nitrite is an oxidizing agent and can initiate the combustion of other materials.							
<b>EXPOSURE LIMITS OF EXPOSURE:</b> Skin: 30m							
Nalco Company 1601 W. Clark Road   Naperville, Illinois 60563-1190   800-455-6222							
1 / 10							

Typical example

**BOTH ONSHORE & OFFSHORE  
THE INJECTED CHEMICALS  
HAVE BEEN MONITORED BY:**

1. Leak records
2. Coupons & Probes
3. Sampling
4. Residual checks
5. Inspections

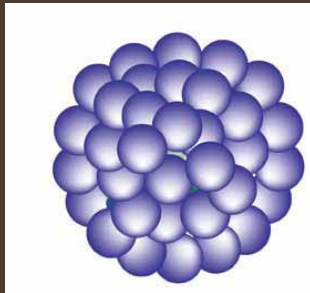
**Finally a Novel Approach to  
Determine if the Chemical  
Inhibitors are Effective & for the  
Proactive Management of  
Internal Corrosion**



## This Technique Detects Micelles

A micelle is a nanoscale aggregate of corrosion inhibitor that forms when a system has reached saturation i.e. corrosion inhibitor has adhered to every available surface (pipe, solids & interface).

Micelle



Cross-section of Micelle



## Micelle Measurement

Micelles are directly measured using a fine stream of fluids passing through a flow cell. A laser then detects the particles and software distinguishes the size, shape, and chemistry of the particle.

We can then analyze the concentration series of the Critical Micelle Concentration (CMC), if required, but this technology relies upon measuring micelles rather than the CMC.

## The Data will give you the following:

- ◉ Ensuring optimization of chemical dosage.
- ◉ Achieving maximum inhibition.
- ◉ Leading to more effective corrosion management currently not offered by other conventional corrosion monitoring methods such as corrosion probes and residual monitoring.

**This independent and accurate information provides operators with a clear understanding of the corrosion and associated integrity risks within their critical process equipment, from the wellhead through to onshore receiving facilities, refining and distribution network.**

## However.....

Failures have (and are) occurring due to internal corrosion.

**Is the inhibitor working?**

**Is it the correct amount?**

**Is the monitoring/sampling working?**

THE LAST METHOD OF CORROSION CONTROL .....

## REPAIR AND/OR REPLACE

**As the term implies simply let it corrode and then replace it.**

This only works if you have monitoring, inspection and surveillance to determine when to remove it from service before it causes leaks, breakdown or failure.

Note that this is the most widely method of corrosion control across all aspects of industry and commercial uses of metal structures and products.

## 7 Methods of Corrosion Control

- Material Selection
- Design of the Structure
- Coatings
- Cathodic Protection
- Alteration of the Environment
- Inhibition
- Repair and/or Replace

## INSPECTION, MONITORING, SAMPLING & OVERALL SURVEILLANCE

Regardless of your choice (s) of corrosion control, or none at all, you must have a handle on your structures integrity. You can do this through:

- Inspections
- Monitoring
- Sampling
- Overall surveillance

## Offshore Vessel Inspection

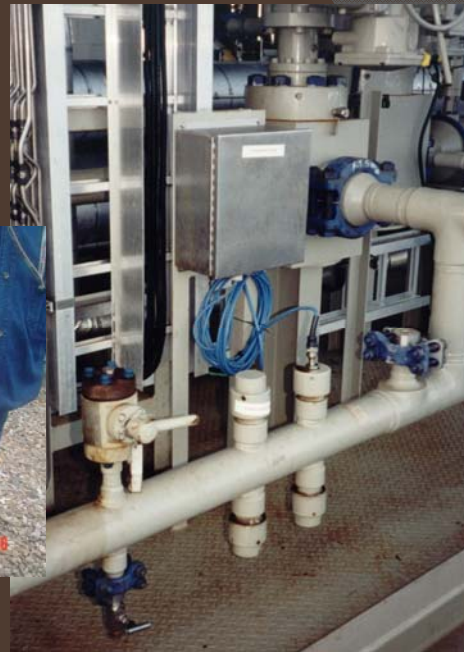


## Corrosion Coupons – Baseline Data

- Most common monitoring method in the world.
- 30-90 day exposure.
- Tells corrosion rate BUT does not tell why or when.
- Main function – are corrosion allowances being exceeded & are the inhibitors working.
- Excellent back up device for Probes – if used.



## ER Probes & Coupons



Sticking your head in the sand (water) is never the solution. Good corrosion control & proactive management of heat exchanger corrosion will optimize your integrity efforts & significantly impact your maintenance cost and planning.



**THANK YOU FOR YOUR  
ATTENTION !**

**ANY QUESTIONS ?**



**Brown Corrosion Services, Inc.**