Proper Removal of Soluble Salts After Detecting Their Presence

--Prevent Premature Coating Failures
--Enhance Straightforward Maintenance Procedures

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<table>
<thead>
<tr>
<th>a. REPORT</th>
<th>b. ABSTRACT</th>
<th>c. THIS PAGE</th>
</tr>
</thead>
<tbody>
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</tbody>
</table>

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Same as Report (SAR)

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19a. NAME OF RESPONSIBLE PERSON

Standard Form 298 (Rev. 8-98)  
Prescribed by ANSI Std Z39-18
Objective: Reduce liability of premature coating failure from corrosion
Goal: Achieve full life cycle coating performance
Reality Check

“Prior to 1995, it is estimated that at least 3 out of 4 contractors suffered major failures during projects or shortly thereafter. Most coatings did not survive more than 5 to 7 years. Now with changes, including (soluble salt remover), we have an approximately 70 to 90% reduction in lifecycle costs, have reduced premature coating failures and increased service life.”

Non vendor specific edit
What are Soluble Salts?

- Ionic contaminants
- Water soluble inorganic compounds
- Primarily chlorides, sulfates, and nitrates
- Non-visible contaminants
- Can bond electrochemically to the metal substrate
Sources

- Marine bodies (sea water-chlorides)
- De-icing salts (chlorides)
- Acid rain (sulfates/nitrates):
  - Stack gases
  - Auto/vehicle emissions
- Chemical processes (many combinations of salts)
- Water and sewage treatment facilities
- Lightning
- Abrasives (chlorides/sulfates)
Chloride ion wet deposition, 2008
Values X 10 = μg/cm² deposited per yr.

Sites not pictured:
AK01 0.1 kg/ha
AK03 0.1 kg/ha
PR20 86.3 kg/ha
VI01 34.6 kg/ha

National Atmospheric Deposition Program/National Trends Network
http://nadp.sws.uiuc.edu
Sulfate ion wet deposition, 2008

Values X 10 = $\mu g/cm^2$ deposited per yr.

Sites not pictured:
- AK01 1 kg/ha
- AK03 < 1 kg/ha
- PR20 22 kg/ha
- VI01 9 kg/ha

Sulfate as $SO_4^{2-}$ (kg/ha):
- Green: $\leq 3$
- Light green: 3 - 6
- Dark green: 6 - 9
- Yellow green: 9 - 12
- Light yellow: 12 - 15
- Medium yellow: 15 - 18
- Orange: 18 - 21
- Dark orange: 21 - 24
- Red: 24 - 27
- Dark red: > 27

National Atmospheric Deposition Program/National Trends Network
http://nadp.sws.uiuc.edu
Sulfuric Acid Reigns Supreme

http://www.turi.org/library/turi_publications/massachusetts_chemical_fact_sheets

such as automotive aerosol parts cleaners and degreasers. PCE is reported to be the chemical most widely found in groundwater contamination at Superfund sites. Read more...

Sulfuric Acid and Fuming Sulfuric Acid

Sulfuric acid is a corrosive toxic chemical that causes direct effects ranging from irritation to burns on the skin, eyes, and respiratory tract. Massachusetts businesses consumed almost 45 million pounds of sulfuric acid, the world's most widely used chemical, in the production of chemicals, electricity, food products, paper products, electronics, textiles, leather goods, and electroplated parts. Fuming sulfuric acid is used to transport high concentrations of acid. Download PDF file (47.99 kB)
Nitrate ion wet deposition, 2008
Values $\times 10 = \mu g/cm^2$ deposited per yr.

Sites not pictured:
- AK01 < 1 kg/ha
- AK03 < 1 kg/ha
- PR20 8 kg/ha
- V101 3 kg/ha

Nitrate as NO$_3^-$ (kg/ha)
- Green: $\leq 4$
- Light Green: 4 - 6
- Medium Green: 6 - 8
- Light Yellow: 8 - 10
- Yellow: 10 - 12
- Light Orange: 12 - 14
- Orange: 14 - 16
- Dark Orange: 16 - 18
- Red: 18 - 20
- Brown: $> 20$

National Atmospheric Deposition Program/National Trends Network
http://nadp.sws.uiuc.edu
Non-visible

- Visually clean substrates are not adequate

- Soluble salts require testing to be detected

- Which salt is the problem? - Primarily dependent on service environment
Microgram per square centimeter

- Pinky fingerprint approximates 1 square centimeter

- M&M candy sliced into one million pieces
  -- single slice = 1 microgram

- Salt packet from McDonalds for fries
  -- dissolved in water
  -- then spread over 1,000 sq ft would deposit

1 microgram per square centimeter

$\mu g/cm^2$
Detrimental Effects of Salts

- Interferes with adhesion
- Accelerates corrosion
- Causes blistering of coatings
A corrosion cell consists of 4 components

- An anode ("-" provided by steel itself)
- A cathode ("+") provided by steel itself)
- A metallic pathway (provided by steel itself)
- An electrolyte (salt + moisture = electrolyte)
Electrolyte—the ONE and ONLY variable we can control is...

- Salts are hygroscopic = Draw moisture

- All liquid applied coatings are permeable and salts will draw moisture through the coating film, thereby providing the electrolyte needed for corrosion activity

- Some coatings are less permeable than others
Osmotic Blisters

- The same hygroscopic action which causes corrosion also causes osmotic blistering.

- The hygroscopic action of salts builds up pressure within a blister which can exceed the bond strength of the coating.
Salt Corrosion Cycle

Iron + Salt + Moisture = RUST + Acid

\[
\begin{align*}
Fe + 2H^+ &\rightarrow Fe^{+2} + H_2 \uparrow \\
Fe^{+2} + O_2 + 4H^+ &\rightarrow Fe^{+3} + 2H_2O \\
Fe^{+3} + 3Cl^- &\rightarrow FeCl_3 \\
2FeCl_3 + 3H_2O &\rightarrow Fe_2O_3 + 6HCl
\end{align*}
\]

Without remediation, repeat reaction cycle
Two distinct methods:
- Conductivity – measures all conductive constituents.
- Ion specific – measures the specific ion of concern; chloride, sulfate, or nitrate.
Conductivity Method

- Measures everything conductive in the sample.
- Many species are not detrimental to the coating film nor induce premature coating failure.
- Measures all minerals.
- Conversion to chloride level is an estimate.
  - Assumes a lab correlation based on 100% chlorides.
  - Conductivity and reactivity are different.
Detecting Soluble Salts

● **Extraction methods**
  - Swabbing (DI water) [25 – 35%]
  - Patch Cell (DI water) [45 – 60%]
  - Wet filter paper (DI water) [??]
  - Magnetic cell (DI water) [45 – 60%]
  - Sleeve method (proprietary acid solution) [80%]
  - Boiling (lab; destructive field sample) [90 – 95%]

● **Quantitative analysis**
  (Sources: SSPC TU4; Third party laboratories)
Chloride Analysis by Ion Detection Tubes

- Sealed ampoule, break both ends and immerse in extract solution
- Cl⁻ read from calibrated tube in PPM and micrograms per square centimeter
- ISO 8502-5
Analysis of Sulfate

- **Electronic turbidity method**
  - Add barium chloride to extract solution to form $\text{BaSO}_4$
  - Measure absorbency/transmittance

- **New Field Test Kit**

- **ISO 8502-11**
  - Maryland Bridge
  - I-95 Delaware
  - Casciano Bridge near Newark A/P
Analysis for Nitrates

- Dip pillow end of nitrate strip into extracted solution for 2 seconds
- Wait 1 minute and compare color on pillow to color on comparator card
  - NASA Gantry
  - St. Lawrence Seaway
BEST PRACTICES (BMP)

- **SSPC Guide**
- **NAV FAC, (DOD)**
- **API 652**

Technical Guide #15
The Society for Protective Coatings
Draft Version
American Petroleum Institute

Specification
Unified Facilities Guide Specifications

Extended Performance
BEST PRACTICES (BMP)

Quality Control
Called in specs—Warranty ONLY

Repeated mentor advice
to test for salts rather
than risk fiasco

Specification
Several pages address
similar to Dewpoint, RH,
Temp. KEY Criteria

Extended Performance

QC Caring
BEST PRACTICES (BMP)

- Mtce washes
- Pre CP
- Not JUST Bare Metal

Quality Control -- Fleets & Structures proper washdown should not harm assets
Concrete and other repairs, intercoat adhesion issues

Extended Performance

Specification
Pipelines/structures when redoing CP clean properly

In Service/Field
NAVSEA: 009-32 Standard Item

- Chloride limit: 3 µg/cm² immersion.
- FY-10: Water wash to meet the limit after abrasive blast.
  - Can require multiple washes.
- FY-11 (Prelim): Allows the use of an approved salt remover.
  - Approval via the F718 from the coating manufacturer

ONR funded research at Carderock and CTC, Johnstown support efficacy and acceptability of an established and time tested soluble salt remover.
Surface Preparation Issue

- Industry standards are generally visual.
- Present coatings cannot tolerate salts.
- Non-visible contaminants are getting more attention.
- Soluble salt removal is critical to coating life cycle performance.
Coatings Economics

Goal: Achieve lowest cost/ft\(^2\)/yr for the expect coating life

<table>
<thead>
<tr>
<th>Total Surface Area:</th>
<th>90,000 ft(^2)</th>
<th>Service: Tank Lining</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insufficient Surface Prep:</td>
<td>$500,000</td>
<td>5 yr coating cycle</td>
</tr>
<tr>
<td>Proper Surface Prep:</td>
<td>$515,000</td>
<td>15 yr coating cycle</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cost/ft(^2)/yr (today’s $):</th>
<th>Cost /yr over 15 yrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insufficient Surface Prep:</td>
<td>$1.11/ft(^2)/yr</td>
</tr>
<tr>
<td>Proper Surface Prep:</td>
<td>$0.38/ft(^2)/yr</td>
</tr>
</tbody>
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Based on actual experience by NAVFAC since instituting revised specifications in 1995.

Coating Life Cycle Comparisons

![Graph showing initial project cost over 15 years for proper and insufficient surface prep.](image-url)
Enclosed Lifeboat
Cable for aft hook

PRIOR VIDEO and these next 5 slides courtesy of US Coast Guard
Case 1

Type: Crude Oil Tanker

DWT: 135,000

Age Of Vessel: 16 Years

Total Steel replacement: 1,200 Metric Tonnes

Renewals were carried out on various internal structures in Cargo & Ballast tanks including areas on the bottom plating.

PRIOR VIDEO and these next 5 slides courtesy of US Coast Guard.
Case 1

The renewal Process on the Ship....

PRIOR VIDEO and these next 5 slides courtesy of US Coast Guard
Case 2

Type: Oil Tanker, DWT: 108,628  Age Of Vessel: 15 Years,
Total Steel renewal was: 150 T. And steel renewal was Limited only to Ballast tank areas...

What happened: Case # 1 = 1200 Tonnes and Case # 2 = 150 Tonnes.
Reason:
The Ship owner in Case # 2 did better Preventive Maintenance during her trading Years!!

PRIOR VIDEO and these next 5 slides courtesy of US Coast Guard
The B-307 was flown to Dulles in 2003 for delivery to the Smithsonian.
Boeing Removes Corrosion Inducing Salts from Ditched Aircraft
Repairs:
Salt removal during Surface Preparation

Why?

- Salts are a leading cause of coating failure today.
- ~80% of coating failures due to salts
- Visual standards used are insufficient.
- Visual standards were adequate for lead paint applications.
Rusty Ammo Magazine
Soluble Salt Analysis and Removal Products Must Be:

- Proven
- Efficient
- Improve Adhesion
- Assist in removal of surface oils
- Cost effective
- Safe
- Easy to use
- Environmentally friendly